RESEARCH AND DEVELOPMENT

AT

THE JET PROPULSION LABORATORY, GALCIT

The California Institute of Technology

Pasadena, California

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I. AN HISTORICAL SKETCH OF THE JET PROPULSION LABORATORY, GALCIT[1]

Basic research in the field of jet propulsion has been in progress at the California Institute of Technology since 1936. It is convenient historically to divide the work into three phases.

The GALCIT Rocket Research Project

The Project was initiated more or less informally in 1936 at the California Institute of Technology with full encouragement of Dr. Theodore von Karman, Director of GALCIT. The original research group was as follows: Frank J. Malina, Hsue-Shen Tsien, A. M. O. Smith, John W. Parsons, Edward S. Forman, and Weld Arnold. The early phases of the research were financed by a gift from Mr. Weld Arnold. Dr. von Karman foresaw the importance of rocket propulsion and the future possibilities of Caltech research in this field.

A theoretical and practical research program, conducted throughout the next two years, was directed primarily toward the design of a high-altitude sounding rocket. The modest program led to the publication of several reports,[2] and to the preparation of several others for

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1 GALCIT is a composite of the capital initial letters in the following: Guggenheim Aeronautical Laboratory of the California Institute of Technology. This abbreviation is widely used both in this country and abroad.

2 "Experiments With Powder Motors for Rocket Propulsion by Successive Impulses." Astronautics, No. 43, 1939, p. 4.
"Characteristics of the Rocket Motor Unit Based on the Theory of Perfect Gases." Jour. Franklin Inst., No. 4, Vol. 230, 1940.
"The GALCIT Rocket Research Project", Astronautics, No. 41, 1938, p. 3. "Flight Analysis of a Sounding Rocket", Jour. Aero. Sci., Vol. 5, 1938, p. 199.
"Flight Analysis of a Sounding Rocket With Special Reference to Propulsion by Successive Impulses", Jour. Aero. Sci., Vol. 6, 1938, p. 50.

aircraft concerns and government agencies. Some of the latter reports suggested application of rocket units as boosters for airplanes, the primary purpose being, first, to shorten take-offs, hence runways; and, second, to boost heavily-loaded planes which, without assistance, could not take off at all from many existing fields.

Army Air Corps Jet Propulsion Research Project, GALCIT Project No. 1

In December, 1938, General H. H. Arnold, Commanding General of the Army Air Corps, requested the Committee for Air Corps Research of the National Academy of Science, consisting of scientists from various research institutions, to sponsor a program for several problems of vital interest to the Air Corps. One of these problems was the development of rocket units suitable for boosting airplanes. Dr. von Karman chose for Caltech the rocket problem and the committee appointed a sub-committee on Jet Propulsion with him as chairman.

On July 1, 1939, sponsored by the National Academy of Science, the AAC Jet Propulsion Research Project was initiated at the California Institute of Technology with Dr. von Karman as Director. Frank J. Malina, John W. Parsons, and Edward S. Forman, members of the original rocket research group, were selected to start the program.

A year later, in July, 1940, the Army Air Corps effectively assumed sponsorship of the Project. During the first two years of the war (1942 and 1943), when the United States was working to make up lost time, the GALCIT Project was constantly expanding.

The Jet Propulsion Laboratory, GALCIT

In January, 1944, arrangements were initiated for the Army Service Forces, Ordnance Department, to participate with the AAF Air Materiel Command in the research program. In the interest of efficient administration, reorganization was called for. On November 1, 1944, the Project became the Jet Propulsion Laboratory, GALCIT. The policies of the Laboratory are determined by an Executive Board appointed by the Trustees of the California Institute of Technology. The Board is responsible directly to the Trustees, two of whom are included in its membership.

In December, 1944, Dr. von Karman, who personally had directed the work of the Project and its reorganization, took leave of absence to become Expert Consultant to the Commanding General, AAF. Dr. Clark B. Millikan was appointed Acting Chairman of the Executive Board; Dr. Frank J. Malina, Acting Director of the Laboratory; and Dr. L. G. Dunn, Assistant Director.

As a result of ASF Ordnance Department participation in the work of the Laboratory, facilities and equipment have increased materially.

Liaison with the military and naval services is maintained as follows:

Col. B. S. Mesick, ASF Ordnance Department
Col. E. H. Eddy, AAF Air Materiel Command
Comdr. H. A. Tellman, USN, Bureau of Ordnance
Lieut. Col. J. C. Nickerson, U. S. Army Ground Services
Major K. S. Jackson, ASF Signal Corps

Col. Mesick in August, 1945, replaced Col. L. A. Skinner, widely known for his work on the development of the bazooka. From June, 1943 to March, 1945, Col. W. H. Joiner represented the War Department.

Facilities and Subcontracts

The Jet Propulsion Laboratory is located within a fenced enclosure covering approximately 40 acres near the western limits of the city of Pasadena, California. Within the enclosure are more than 80 structures of widely-varied types. Dominating the entrance is the Administration Building. Beyond it are:

1. Numerous test pits for the development of propulsion systems for solid- and liquid-propellant rockets, and for ramjets and turbojet engines;
2. Laboratories for research in high-temperature resistant materials, and the processing of solid propellants;
3. A towing channel for research on underwater missiles;
4. Machine, sheet metal, and welding shops.

Under construction is a compressor house to supply highly-compressed air for thermojet research.

The staff at the Laboratory numbers more than 385. The facilities with equipment are valued approximately at $3,000,000.

Various laboratories on the campus of the California Institute of Technology also are utilized; for example, the 10-foot wind tunnel of the Guggenheim Aeronautical Laboratory. Expert consultation on special problems is provided by staff members in several departments. A Chemistry Group, under the direction of Dr. B. H. Sage of the Department of Chemical Engineering, has been conducting special research for the Laboratory for several years.

A test station for the investigation of large, liquid-propellant rocket units is being operated by the Laboratory for the ASF Ordnance Department at the Muroc Army Air Base, California.

Numerous contracts under the different research projects have been placed with industrial organizations in various parts of the United States, including many companies throughout the Los Angeles area.

II. JATO (Jet-Assisted Take-Off for Aircraft)

The research begun in 1939, under the auspices of the National Academy of Science, continued the modest work that had been initiated in 1936. It was understood, as it continues to be, that the Laboratory primarily should be concerned with the solution of basic research problems, to enable the Armed Services to develop equipment of novel type.

One of the immediate objectives of the three young men appointed to carry out the research program for the first year was to develop two types of rocket motors; one, utilizing the energy of a solid propellant, the other, of a liquid propellant. Both types had to be capable of delivering a constant and sufficient thrust for a period long enough to assist a plane to take off and reach an altitude considered safe to continue its flight unassisted. The period specified was of the order of 10 to 30 seconds.

The first year was devoted mainly to a survey of early experience in the field and to study of the fundamental properties of propellants. How the Project developed a successful, solid-propellant rocket motor is told first.

Solid-Propellant Rocket Motors

In 1939, little information was available on powder rockets with duration longer than one second. Two ways suggested themselves to solve the problem of delivering a prolonged thrust. The first was to install in a plane a group of motors loaded with fast-burning solid charges, and to fire them one at a time in quick succession so as to produce a prolonged thrust. Experiments conducted by a number of investigators were discouraging in that successive firing at split-second intervals was not dependable; hence thrust was delivered not constantly but by fits and starts, strenuous on pilot and plane alike. The second way that suggested itself was to develop a restricted-burning propellant that would burn at one end only, like a cigarette, in order to produce a constant, prolonged thrust. Profiting by knowledge of the difficulties encountered in attempts to develop the first method, the Project directed its efforts toward development of the second.

The first experiments were conducted with commercial stick powders, made to specification. The experimental motor was built of steel tubing two feet long and one inch thick. The inside diameter was three inches. One end was plugged; the other end was fitted with a pipe flange eight inches in diameter. The motor nozzle also was fitted to a flange to match the one on the motor so that the nozzle and motor were connected by bolting the two flanges together. The bolts, made of relatively soft steel, were of a diameter calculated to give way when pressure inside the motor became dangerously high; thus the nozzle was permitted to fly off and save shattering the motor. Powder charges were ignited at the nozzle end of the motor by an electric squib; near the nozzle end, also, the motor was tapped to permit pressure measurements.

One of the dangers anticipated in the operation of the experimental motor was that, under the pressure created, the gaseous flame at the end of the solid powder stick might strike down between the charge and the chamber wall. If it did, the whole charge would burn so rapidly that the result might be an explosion. Or, possibly, the transfer of heat down the walls of the chamber might ignite the whole charge. To prevent such possibilities, experiments were conducted with various types of liners whose function it was to seal off effectively the space between the powder and the chamber walls so as to restrict burning to the end of the stick.

Another danger anticipated was that a stick of powder might crack or crumble under the high pressure induced by combustion, hence burn too fast and explode. To minimize this danger, powder sticks were molded in an hydraulic press under very high pressure.

Over a two-year period, with personnel augmented only in the second year, the Project made many hundreds of tests. Different powder combinations were tried with different loading techniques, and with different nozzles of various design, and with different construction materials. By the summer of 1941, a dependable, small-scale motor and a propellant had been developed and put into limited production for experimental purposes. The motor delivered a maximum thrust of 28 pounds for 12 seconds. Unloaded, the unit weighed 10.7 lb.; the powder charge weighed approximately 2 lb.

The propellant developed, named GALCIT 27, was an amide powder prepared from commercial ingredients. Each two-pound charge had to be pressed into the combustion chamber of the motor in a series of 22 separate increments, each under a pressure of 18 tons. Loading with large, hence fewer, increments, or loading under lighter pressure, produced powder sticks that were likely to explode.

The Ercoupe Flight Tests: Calculations had revealed that the combined thrust of six of the new motors was sufficient to justify their application to a light airplane. It was feasible, moreover, to fire six of the units simultaneously.

The Germans already had used jet propulsion to assist gliders into the air. We Americans had not. Our knowledge was limited to calculations based upon theory. Obviously, data based on actual tests were much needed to check against theoretical predictions of the distance jet propulsion could shorten take-off, with and without overloading a plane. If experiment proved the theoretical calculations to be sound, then they could be relied upon to predict the performance of any airplane equipped with jets. It was desirable to know, too, what effect the jet thrust would have upon the stability and control of an airplane, and what effect the hot jet blasts would have upon the plane structure.

For flight tests, therefore, the Air Materiel Command made available to the Project a low-wing monoplane, known as the Ercoupe. Its weight, empty, was 753 pounds. Captain H. A. Boushey, Jr., the test pilot, flew the plane from Wright Field, Dayton, Ohio, to March Field, near Riverside, California. Two identical assemblies, each incorporating three rocket units, were installed on the plane, one assembly under each wing. As a safety precaution in case of explosion, each unit was designed so that both the exhaust nozzle and the combustion chamber were free to fly clear of the plane. An electrical switch, mounted on the control panel, controlled ignition of the rocket motors.

The test program was conducted at March Field, August 6 to August 23, 1941. Witnesses, including both Army and Navy personnel, viewed the first take-off in the United States of an airplane assisted by jet propulsion. With the exception of several failures in preliminary trials, the tests were successful, the experimental results checking satisfactorily the theoretical predictions.

With jet assistance, the distance required for the plane to take off was shortened from 580 feet to 300 feet, a saving of 48.3 per cent. The time required to take off was shortened from 13.1 seconds to 7.5 seconds, a saving of 42.8 per cent. With an overload of 285 pounds, the distance was shortened from 905 feet to 438 feet, a saving of 51.6 per cent. The time was shortened from 18.8 seconds to 9.5 seconds, a saving of 49.4 per cent.

The operation of the jet units, 152 being operated in succession without the failure of a motor, had no adverse effect upon either stability or control or upon the plane structure. The pilot remarked, in fact, that the auxiliary thrust had made easier the handling of the plane throughout the take-off run. In short, results of the flight tests fully justified proceeding with plans to develop and test both solid- and liquid-propellant jet motors designed to deliver 1,000-pound thrust.

<u>Later Developments of JATO</u>: Simulating a period of 28 days, tests were run to determine the keeping qualities or storage life of the new propellant, GALCIT 27. Under test it deteriorated too fast for use in the services. Shrinkage of the powder stick tended to draw it away from the liner, thus breaking the seal of the propellant across the diameter of the combustion chamber and permitting flame to penetrate

below the surface and cause an explosion. In September an experimental program was started to improve both liner and powder.

Early in 1942, while the program was still in progress, the report of the Navy Officer who had witnessed the Ercoupe flight led to action. The Navy contracted with the Project to develop for experimental purposes a jet unit, with acceptable storage life, to deliver 200-pound thrust for eight seconds. The Project planned to incorporate in the unit the improvements expected to result from the program in progress. In May a greatly improved solid propellant and a suitable motor were ready for testing. The improved propellant was designated as GALCIT 46.

Meantime, the Project had been investigating the whole subject of solid propellants with the intent to develop one better than GALCIT 46. The latter had good storage life, but good only within too narrow a range of ambient temperatures for use in global warfare, which demands propellants suitable for use anywhere from Alaska to Africa.

To determine chances for success with any formula combining ingredients essential to all types of propellant like GALCIT 46, an investigation was made of the crystalline properties and the thermal expansion rates of such ingredients. The investigation suggested that both crystalline changes and expansion rates, over a wide range of temperatures, varied so that probably any compound would crack and disintegrate in burning.

Ballistite, a different type of propellant, also was investigated. A compound essentially of nitrocellulose and nitroglycerine, the type then available had a much-desired high-energy content; but it had two serious drawbacks. First, the high temperature of combustion made motor design difficult, and the hot blast made it unsuitable for use on carrier decks. Second, the release of its energy content is too sensitive to temperature changes. For example, a rocket unit loaded with ballistite and designed to deliver 1,000-pound thrust at 90°F could deliver at most only 600-pound thrust at 40°F. Though the duration of thrust at the lower temperature would be lengthened, an aircraft assisted by such thrust might fail to take off from a short runway.

After exhausting other possibilities, the investigators turned to a radically different type of propellant made by a different process, namely casting the ingredients in a mold rather than compressing them. What they turned up with was designated as GALCIT 53, the number being suggestive of the amount of developmental work the Project had done on solid propellants.

First tests of the molded propellant were made in June, 1942--by coincidence while the test program on GALCIT 46 was still running its course. GALCIT 53 showed such promise that the Project decided to give it priority over the other, to hasten its full development.

The oxidizer in GALCIT 53 was potassium perchlorate, in form a white powder. In addition to being plentiful, it combines the optimum in available oxygen, heat of combustion, and chemical and physical stability. The fuel in the new propellant was a special type of asphalt; added to it was a small percentage of oil with an asphalt base.

The mixture was prepared by heating the asphalt and oil in a mixing kettle to a temperature of 350°F, then stirring in the perchlorate. Before the combustion chambers were loaded with the finished propellant, they were lined with a hot mixture of asphalt and oil.

When the propellant had cooled sufficiently, it was scooped into the combustion chambers, which were bounced a few times to assure uniform settling, then set aside for the propellant to harden.

In its finished form, GALCIT 53 is a black plastic, at ordinary temperatures resembling stiff paving tar. It can be detonated with difficulty if at all. Only with patience can it be ignited with a match flame; but once ignited it burns fiercely, emitting a white light and dense white smoke. Burning in a combustion chamber under pressure of 1,800 pounds per square inch, the propellant gives an average exhaust velocity of 5,300 feet per second at an average burning rate of 1.25 inches per second.

The new asphalt-base propellant had several advantages over all the earlier ones. It was easier to prepare and ingredients were more readily available; it could be stored at wider temperature limits, and within those limits it could be stored indefinitely without deteriorating, whereas the earlier propellants had a tendency in storage to pull away from the liner, leaving tiny cracks, which led to explosions.

Units loaded with the new propellant were recommended to be fired at temperatures between 40°F and 110°F. Much above the recommended temperature it became viscous and flowed. Therefore, it was imperative that invariably the JATO units be stored right side up.

The rocket motor designed for use with GALCIT 53 was constructed to meet specifications set by the Bureau of Aeronautics, Navy Department. It was approximately 13 inches long and five and one-half inches in diameter. The nozzle plate, which was screwed into the end of the combustion chamber, was equipped with a nozzle, an ignition squib, and a safety device, called a blow-out plug. The plug was a copper disk designed to blow out at a pressure approximately of 3,000 pounds per square inch, thus permitting excess gases to escape. To prevent danger from flying pieces and temporary excessive thrust of the jet unit at the instant of failure, a cap with four holes in its side walls was screwed over the disk. The holes in the cap permitted the gas flow to emerge in four jets which mutually canceled thrust in any one direction.

Once the developmental work was finished on the rocket unit just described, the Navy contracted with the Aerojet Engineering Corporation of Pasadena to manufacture a limited number for experimental purposes. In 1943 the Navy, having a greater use for jet-assisted take-off than the Army, began placing large orders for motors delivering not only 200-pound thrust, but 500- and then 1,000-pound thrust. Developmental work on these larger units was carried on both by the Laboratory and by Aerojet. Today JATO is a commonplace word among fliers throughout the Armed Services.

Since 1942, most of the work done by the Laboratory to improve solid propellants has been directed toward widening the temperature limits for safe operation. In 1943, the Laboratory developed GALCIT 61-C, which the Navy continued to use until the war ended. Increasing the size of rocket units utilizing solid propellants is largely a matter of scaling up smaller models. Application of solid propellants to other kinds of vehicles, however, is another subject. It will be dealt with in a later section.

Liquid-Propellant Rocket Motors

Simultaneously with the development of solid-propellant motors in July, 1939, the Laboratory undertook the development of liquid propellants more satisfactory than any then in use.

One of the initial difficulties was to find a suitable liquid oxidizer for the liquid fuel which, it was taken for granted, would be some one of several easily obtainable. The conventional choice of an oxidizer would have been oxygen itself. Commercially, it was available in both gaseous and liquid forms; but gaseous oxygen is impracticable for use either in a rocket or airplane because storage tanks strong enough to contain it are prohibitively heavy. Liquid oxygen was also objectionable because its physical properties made it difficult either to store or to transport; thus its use in mobile warfare was limited.

But if pure oxygen had its drawbacks, so had chemical compounds that liberate free oxygen when combined with suitable fuels. Earlier experimenters had found that, if the compounds worked at all, they were likely either to produce residues that eroded exhaust nozzles, or else cause some other difficulty that seriously lowered the efficiency of motors.

Red Fuming Nitric Acid as an Oxidizer: As part of their work between 1936 and 1939, the GALCIT Research Group had made some preliminary study of liquid oxidizers, starting with a review of the data their predecessors had made available. After four months of work in 1939, they had reduced to four the compounds that recommended themselves for further study. Within an additional six weeks, by still more rigorous process of elimination, they had reduced the four to one;

namely, red fuming nitric acid, a solution of nitric acid and nitrogen dioxide, with the chemical formula HNO_3NO_2 (referred to hereafter simply as nitric acid or acid).

It was recognized that, on account of its poisonous properties, the chemical would have to be handled carefully; and that its corrosive characteristics would restrict its use exclusively to those metals and other materials it could not corrode. The limitations, however, were not considered insuperable. But it remained to be seen whether the acid could be made to decompose and burn completely with a fuel. Preliminary tests, completed just before Christmas, 1939, proved that it did, and notably well with gasoline and benzine. The tests were conducted in open crucibles.

Work began on the design of a small motor and accompanying apparatus to test the behavior of the nitric acid and fuel in a combustion chamber, as well as to study methods for cooling the motor, for injecting the fuel, and for measuring thrust. The finished assembly consisted of the following: a device to measure thrust, a rocket motor with a conventional spark plug let into the side wall, two propellant-supply tanks, and a cylinder of nitrogen under pressure to inject the liquids into the combustion chamber.

Because the combustion temperature for liquid propellants under pressure is higher than the melting point of many metals, precaution had to be taken. The combustion chamber, the end plug, and the nozzle block were solid copper; for, in spite of its relatively-low melting point, the metal absorbs heat faster than any except silver; hence copper could be relied upon to keep the temperature safely below the melting point--provided, of course, the motor was operated only for short periods. The motor walls were very thick, moreover, because the more of the metal there is, the more heat it absorbs.

In May all was in readiness to test the behavior of nitric acid and fuel in a combustion chamber. All the tests performed were an unqualified success. Judging by the clean flame, combustion had been almost if not quite complete.

The Project celebrated its first birthday, July 1, 1940, by initiating a program for the development of nitric acid as an oxidizer. For the time being at least, the many difficulties inherent in the development of liquid oxygen could be forgotten. The way was open to develop, as directed by the Army Air Corps, a liquid-propellant rocket unit to deliver 1,000-pound thrust for approximately one minute.

<u>Development of the First 1,000-Pound Thrust Motor</u>: Engineering practice suggested that the development of the projected motor and its assembly should proceed, not in a single step from a small model to the full-size one, but through intermediate models graduated in size, in order to minimize the difficulties likely to arise as scale increases. Another reason for making haste slowly was that manpower and facilities were strictly limited. As a starter, then, the Project designed a unit to deliver thrust of 200 pounds.

Time out to clear ground and construct buildings during the summer of 1940 delayed development of the projected unit. But late in February, 1941, it was assembled in the new test pit designed to house it. One end of the structure was left open to expedite the escape of fumes. The open end faced into a hillside, where the solid earth should act as a cushion for flying missiles in case of explosions.

As an added precaution, walls were built of heavy railroad ties set upright like the timbers in a stockade.

In the first test, the motor blew up. But safety bolts sheared as calculated, and the three essential parts of the motor remained intact. In all, some fifteen tests on the motor failed. Meantime, a Chemistry Group, under direction of the Department of Chemical Engineering at the California Institute of Technology, undertook to investigate the reaction of nitric acid and gasoline.

While the tests on the first motor were still in progress, a second motor with 200-pound thrust was speeding its way from the design board to the machine shop. The end plate, made of stainless steel, was utilized as an injector, with four small orifices; two for gasoline, and two for nitric acid. The combustion chamber was a length of steel tubing with a spark plug let into the wall. The exhaust nozzle was copper.

The chief difficulty in tests on the unit was with ignition. Unless it was instantaneous--and often it was not--such quantities of propellants collected in the chamber that, when they did ignite, the motor blew up.

In May, a third motor was ready for testing. It blew up on the first test, the blazing propellants setting fire to the test pit.

While repairs were under way, work was going forward on a fourth motor, which incorporated a new injector design. Six orifices, manifolded and drilled in a circle about the center of the end plate, injected gasoline; twelve more, manifolded in a larger circle, injected acid. All orifices were drilled at an angle so that the propellants impinged at a common focal point, thus mixing and dispersing the liquids in a fine spray. To insure a smooth stream flow, each orifice was equipped with a carefully-machined tip that screwed into place. The spark plug was protected by a safety shield to prevent the propellant components from short circuiting it.

Early in July, 1941, the fourth motor was ready for testing. It worked. Operation throughout the test period justified the next step in the developmental program, the design of a motor to deliver 500-pound thrust.

Except for a single explosion, the test program carried out on the 500-pound thrust motor was successful. The program yielded invaluable information, notably:

1. how to reduce the pressure of the nitrogen, which fed the propellants to the combustion chamber, thus permitting a simpler and lighter propellant-supply system;
2. how to select the propellant mixture ratio to control combustion temperature;
3. and how to design an exhaust nozzle that the hot gases eroded less than any earlier one.

Tests on the 500-pound thrust unit coincided with the Ercoupe flight tests at March Field. By September, three important decisions were made:

1. to proceed at once with a design for a liquid-propellant rocket motor, to deliver 1,000-pound thrust;
2. to increase the personnel, and to divide it into two groups; one to develop motors, the other to work on problems of installation and controls that had to be solved before the projected units could be tested in an airplane;

3. to request the AAF to provide a plane suitable for mounting and testing twin assemblies, each with thrust of 1,000 pounds.

The first rocket motor designed to deliver 1,000-pound thrust was ready for testing in October. It differed from the preceding one not only in scale but in that it was equipped with two spark plugs instead of one, and with a manifolded injector having 45 orifices instead of 18.

The first tests were a decided disappointment. Sometimes ignition was delayed; sometimes it failed altogether. And in addition a new trouble appeared. Sporadically, the motor began to pulse, slightly at first but increasing in intensity until at the fourth or fifth throb, if not shut off, it would blow up.

For four months the Motor Group labored to improve ignition and combustion, and to stop throbbing. In the end, though ignition was improved so that it worked possibly 80 per cent of the time, throbbing still presented a baffling problem.

Aniline as a Fuel: At the Naval Experiment Station, Annapolis, Maryland, another group of investigators had been having trouble with the combustion of nitric acid and gasoline. They suggested, talking it over with Dr. Malina who was visiting the Station, that perhaps the addition of aniline to the gasoline might help. Dr. Malina telegraphed his group in Pasadena, suggesting aniline, not simply as an additive to gasoline but as a substitute for it.

Put into practice, the suggestion worked. Not only did it work, but it led to the discovery in the United States that aniline is spontaneously combustible with red fuming nitric acid. Thus, at once, ignition, combustion, and throbbing problems were solved.

But there was still a serious question to be decided. Should the attempt be abandoned to develop gasoline as a fuel in favor of aniline? Gasoline has a great advantage for military operations in that it is available, as are facilities for handling it and operators who know how. Aniline, on the other hand, though available, is a toxic liquid that affects the blood, and it is readily absorbed through the pores of the skin. If adopted, facilities for handling it would have to be developed, and crews would have to be taught how to use it properly. But the decision was made, in the end, to adopt aniline.

The first two injectors designed to spray aniline and acid into the combustion chamber were failures. In the third, eight jets of liquid impinged in pairs equidistant from one another. Each of the four resulting jets formed a stream practically parallel with the walls of the combustion chamber so that little of the propellants washed against the chamber walls. With the third injector, combustion in the 1,000-pound thrust motor was instantaneous and infallible.

The A-20A Flight Tests: The chief purpose of the projected flight tests was to gain information about air-borne equipment and control devices essential for practical application to liquid-propellant rocket units.

The choice of an airplane suitable for mounting and testing a pair of units, each with 1,000-pound thrust for a duration of approximately 25 seconds, settled upon a bi-motor Douglas bomber, the A-20A. The weight of the plane, empty, was 14,000 pounds. Its tail surfaces were high enough to clear the jets from the motors; and the nacelle tail cones, which projected rearwards well behind the wings, provided ample space to house a unit. This space is used sometimes to mount a machine gun firing aft.

The Design and Control Group was responsible for all installations. Early in the winter of 1941, the Group was engaged in preparing a complete mockup, or dummy, of the motor and all the equipment, exactly as the assembly would be mounted in the A-20A. The work was expedited in January when the AAF sent detailed drawings of the plane and an actual nacelle cone to work with.

A simplified description of the assembly and its installation in the plane is as follows: the nitrogen tanks to supply pressure for the propellants were located in the forward bomb bay, with a line leading to each nacelle cone. In each cone were located a motor, two propellant tanks, and a valve--actuated by hydraulic pressure--to control the propellant supply. The end of each cone was cut off in order to give the exhaust nozzle necessary clearance. In the rear cockpit were six pressure gauges to measure the performance of the installation, and eleven controls, all accessible to the operator stationed there.

Among the numerous safety precautions taken, two especially deserve notice. Each motor, mounted on slides, was restrained by hydraulic thrust jacks in order to permit recoil so that, if there was an explosion, the plane would not have to absorb the forward thrust of the combustion chamber. The purpose of the second precaution was to avoid destructive thrust if the nozzle was blown off. It was coupled to the motor body by a pair of shock absorbers so that the two units could react upon one another instead of one of them reacting on the plane; moreover, both of them would be brought to a full stop within a few inches.

The flight tests with the A-20A were conducted at the AAF Bombing and Gunnery Range at Muroc, California, April 7 to April 24, 1942. The pilot was Major P. H. Dane. During the tests 44 successive runs were made without any misfires or explosions. For the first time in the United States, an airplane had taken off, assisted by liquid-propellant rocket units.

Like the earlier tests with the Ercoupe, those with the A-20A were highly successful. Reduction in distances required to take off were very close to those predicted. And the experience gained in the development of the experimental unit cleared the way for the design and manufacture of a service type. Accordingly, the Aerojet Engineering Corp. took over. Development of both larger and different types has been carried out since by Aerojet and by the Laboratory, working cooperatively and independently.

III. JET PROPULSION UNDER WATER

The Hydrobomb

In 1943, the Armament Laboratory of the AAF arranged with the Jet Propulsion Laboratory, GALCIT to develop a missile to be launched from a bombing plane and to be propelled at high speed under water by means either of solid- or liquid-propellant rocket units.

The missile at present under development is called the hydrobomb. Two different prototype models have been built for the AAF; one by the Westinghouse Manufacturing Company, and one by the United Shoe Machinery Company. The Laboratory has designed and constructed half-scale models of these prototypes.

A full-scale model, constructed by the United Shoe Machinery Company, is more than 10 feet long, with a maximum diameter of 28 inches. Designed to be launched at speeds up to 350 miles an hour, and to travel under water at 70 miles an hour, the missile is driven by a solid-propellant rocket unit delivering 2200-pound thrust for 30 seconds. The range of the missile is 1,000 yards; gross weight, approximately 3200 pounds; and the weight of the warhead, 1250 pounds.

Facilities for Research

Of fundamental importance in the research program undertaken to develop the hydrobomb was basic information upon the hydrodynamic characteristics of the proposed missile. It was imperative to know, for example, the effect of jet propulsion upon stability and performance of an underwater missile, and the effect of jet propulsion upon cavitation, a phenomenon well known to designers of high-speed underwater craft.

The cause of cavitation may be explained as follows: when a streamlined body moves through water, the water pressure at certain portions of the surface is reduced. As the speed of the craft increases, the pressure further decreases until, at a certain critical value, the pressure drop is so great that the water vaporizes and forms bubbles. The bubbles cling to the surface where they are initiated. Extensive cavitation seriously impedes the motion of an underwater craft by increasing its drag in the water. Designers, therefore, exercise every precaution to reduce it to a minimum.

Information concerning fundamentals such as those suggested is procured through the interplay of theoretical and experimental methods.

One acts as a check upon the other until at last all the desired information is at hand.

The experimental part of the research program set up to develop the hydrobomb demanded elaborate apparatus, useful also in other investigations of propulsion under water. This apparatus is a towing channel equipped with facilities for observing and measuring the behavior under water either of models or of full-scale craft.

The towing channel built at the Laboratory is open to the weather. Constructed of reinforced concrete, it is 500 feet long, 16 feet deep, and 12 feet wide. Astride the channel rides a towing carriage, the wheels mounted on carefully-leveled steel tracks running the length of the channel. The carriage, driven by an electric motor, can run faster than 40 miles an hour. Originally, it was driven by three liquid-propellant rocket units.

Preparatory to a model test, the carriage is raised on hydraulic jacks. Suspended from the center of the carriage is a strut, adjustable to any length up to 12 feet. A model is attached to the free end of the strut. When the carriage is lowered, the model is submerged ready for testing. Electrical strain-gauges installed within the model connect through the strut with an oscillograph in the carriage. As the carriage tows the model the length of the channel, the strain-gauges measure the hydrodynamic forces acting upon the model, and the forces are recorded by the oscillograph. The quantities to be measured are known technically as lift, drag, and pitching moment.

On one side of the channel, midway between the ends, is an underground observation room with a glass window let into the channel wall.

The behavior of flow over the surface of a model is studied visually and recorded by cameras.

One of the chief difficulties encountered in the operation of the towing channel has been to overcome vibration in the carriage when it runs at high speeds, for vibration seriously interferes with the accurate recording of the oscillograph. Operation has been improved considerably by coating the steel wheels with rubber and by stiffening the carriage structure as a whole.

Research on the Hydrobomb

Responsibility for the actual design of different experimental models of the hydrobomb rests with agencies other than the Jet Propulsion Laboratory. The responsibility of the Laboratory in the development of the models is to measure the lift, drag, and pitching moment; in other words, the hydrodynamic forces exerted upon a model in motion. The shape of a model and the size of the control surfaces (fins and rudders) influence not only the behavior of these forces but the extent of cavitation as well.

The motor used for testing the hydrobomb model burns a solid propellant delivering the specified thrust of 2200 pounds for a duration of 30 seconds. A long exhaust nozzle was necessitated by the required length of the missile; and the heat the nozzle developed had to be ascertained accurately to make sure it was not great enough to affect the operation of control mechanisms installed adjacent to the nozzle.

A special propellant had to be developed for the hydrobomb because its geometry is such that a solid propellant must be made to burn at the rate of one inch per second if the missile is to deliver a 2200-pound thrust for 30 seconds. The result was GALCIT 65, a modification of GALCIT 61-C, an earlier development of the Laboratory. Work on the new propellant proceeded rapidly after potassium nitrate was introduced in order to slow the burning rate.

The new propellant, sealed into rocket motors with the standard liner mentioned in connection with JATO units, was subjected to tests simulating launching from an airplane flying at different velocities up to 400 miles per hour.

A rocket unit launched at high velocity hits the water with such terrific force that it was feared the impact might crack the propellant or liner, or else separate the propellant from the liner, or perhaps separate the liner from the steel walls of the motor. Any one of these mishaps would render undependable the firing of a unit. It was necessary, also, to determine the effect of temperature upon the ability of the propellant and liner to withstand the impact following launching.

The test procedure was to launch a dummy torpedo fitted with a loaded, solid-propellant motor, then later to fire the unit in a test pit where, if it exploded, it would do no harm. Results showed GALCIT 65 capable of withstanding impact resulting from launching velocities up to 385 miles per hour. The launching tests were made at the Torpedo Launching Range developed by the California Institute of Technology for the Navy at Morris Dam, California.

IV. THE ORDCIT PROJECT

Objective

The ORDCIT Project was initiated as the result of a memorandum submitted by Dr. von Kármán, H. S. Tsien, and F. J. Malina to the Ordnance Department in November, 1943. In January, 1944, Major General G. M. Barnes requested, in a letter addressed to Dr. von Kármán, that the Jet Propulsion Laboratory undertake a research and development program on long-range, jet-propelled missiles. The project was the first of its kind in the United States.

The Project is based upon a contract between the ASF Ordnance Department and the Laboratory. As a result, the AAF and the Ordnance Department utilize cooperatively the staff and facilities of the Laboratory.

The primary purpose of the contract is to obtain fundamental information to assist the development of long-range, jet-propelled missiles, together with suitable launching equipment. The contract calls for the design and fabrication of prototype test vehicles, delivered ready for firing tests--the actual test programs to be carried out under the supervision of the Ordnance Department at whatever ranges they designate. But the scope of the contract is sufficiently broad to include basic research on:

1. Propellants and materials essential for jet-propulsion devices,
2. Equipment for the remote control of guided missiles,
3. The aerodynamics of guided missiles (i.e., missiles stabilized and guided by fins and wings).

The following account of the research and development at present under way is in the nature of a progress report on work being done under the ORDCIT Contract.

The PRIVATE A and the PRIVATE F

The first step toward the primary objective--a long-range guided missile propelled by rocket thrust--was the design and fabrication of the PRIVATE A. Its purpose was to provide experimental data on the effect of sustained rocket thrust on a missile stabilized by fixed fins, and to provide knowledge on the use of booster rockets for launching missiles.

Approximately 8 feet long, the PRIVATE A tapered to a sharp nose designed for supersonic flight, and it was guided at the aft end by four fins, each extending 12 inches from the motor body. Its gross weight was more than 500 pounds, including a pay load of 60 pounds. Driven by a solid-propellant rocket unit manufactured by the Aerojet Engineering Corporation, the missile delivered thrust of 1,000 pounds for over 30 seconds.

The booster unit, which supplied auxiliary thrust to initiate quick take-off, was a steel casing designed to mount four Ordnance aircraft armament rockets, each 4 1/2 inches in diameter, and manifolded so as to insure simultaneous firing. Open at the center to permit clearance of the jet blast from the PRIVATE, the booster was designed to deliver thrust of more than 21,500 pounds. Devices were installed to prevent rotation in the launcher both of the booster and the PRIVATE; and both vehicles were held in intimate contact by a shearing pin in order to prevent the destructive impact which otherwise would have occurred when the booster unit was fired, as it had to be, an instant after the main motor of the PRIVATE was fired.

The launcher was a rectangular steel boom of the truss type, with four guide rails inside its rigid structure. The boom was mounted on a steel base by means of a pivot joint so that it was adjustable both laterally and vertically. The length of the boom was 36 feet. The function of its length was twofold; to support the missile and guide it on its course until it attained velocity sufficient to gain aerodynamical stability, and to allow the booster unit to burn completely and to disconnect itself from the PRIVATE before the missile cleared the launcher.

Firing tests of the PRIVATE A were carried out at Leach Spring, Camp Irwin, near Barstow, California, December 1-16, 1944. Twenty-four rounds were fired in all. The average range was approximately 18,000 yards; the maximum 20,000 yards (11.3 miles).

In the spring following the tests of the PRIVATE A, another experimental rocket was ready for testing. It was designed to explore the effect of lifting surfaces upon a guided missile. Called the PRIVATE F, it was essentially the same rocket as the PRIVATE A; but, instead of four symmetrical guiding fins at the aft end, it had one fin and two horizontal lifting surfaces with a total span of nearly 5 feet. At the forward end of the missile, to trim it in flight, were two stubby wings, their total span, less than 3 feet.

Few changes were made in the booster for the PRIVATE F, but the spread of the wings and lifting surfaces on the missile dictated changes in the launcher. It had two rails above, rather than four inside, the steel framework.

The firing tests were at the Hueco Range, Fort Bliss, Texas, April 1-13, 1945. The Range was equipped with radar for tracking the flight path of missiles, and with cameras for recording initial trajectories. Seventeen rounds were fired. Though the tests provided valuable data of a highly-technical nature, they demonstrated that a missile with lifting surfaces requires flight control equipment for regular flight.

The WAC CORPORAL

By far the most spectacular missile the Laboratory has developed is a rocket with the code name WAC CORPORAL. It was tested during the autumn of 1945. Some information about the missile was released in March, 1946. Now that the ORDCIT contract has been reclassified, the Army Ordnance Department is at liberty to release more about the story of the WAC CORPORAL from its inception to the flight test already reported.

Preliminary Problems: In December, 1944, the Ordnance Department requested the ORDCIT Project to investigate the feasibility of a high-altitude rocket to carry 25 pounds of meteorological equipment to an altitude of at least 100,000 feet, or almost 19 miles, in accordance with a requirement of the Signal Corps.

Early steps toward the fulfillment of the assignment included a series of studies. First, a theoretical study was made to determine whether, with the rocket propulsion systems available at the time, the requested performance for the rocket could be achieved.

When the theoretical study indicated that the requested performance was possible, an investigation was begun to determine the required weight of the missile, its thrust, and the duration of thrust; for upon these and other requirements its design would be based.

The investigation also evaluated alternatives for meeting certain of the requirements. It was decided, for example, to initiate flight with a booster, and to use a launching tower for guidance of the missile until it achieved a velocity safe for holding vertical flight. The alternative would have required equipment even more complicated than a launcher and booster to control the flight of the missile on its upward course.

Innumerable essentials of the proposed design, including both missile and auxiliaries, called for technical knowledge obtainable only through experiment. Therefore, as a prerequisite to the actual designing of many essential parts, an experimental program had to be carried out.

A feature of the experimental program was the fabrication and test of a one-fifth scale model of the WAC CORPORAL. The purpose of the test was to determine whether three tail fins would suffice instead of the usual four, and whether the missile-booster combination chosen provisionally would perform as anticipated. Tests of the BABY WAC, made at Goldstone Range, California, July 3-5, 1945, confirmed the choice of three fins and the missile-booster combination selected.

The missile, booster, launcher, and other equipment as finally approved and fabricated for the tests are described herewith.

The Missile: Approximate outside dimensions of the WAC CORPORAL were: length 16 feet from the needle-pointed nose to the tri-finned tail; diameter 12 inches. The gross weight was 665 pounds. Empty, the missile weighed less than 300 pounds. It delivered thrust of 1500 pounds for 45 seconds.

The source of power was a liquid-propellant rocket motor developed by the Aerojet Engineering Corporation. The motor was cooled by the flow of fuel within the jacket walls just before it entered the combustion chamber. The Laboratory adapted the motor to utilize nitric acid as an oxidizer; and aniline as a fuel--a spontaneously-combustible propellant combination the Laboratory had begun to develop in 1942, shortly after the test flight of the A-20A.

The pressure required to force the propellants into the combustion chamber was supplied by compressed air instead of nitrogen, conventionally used for the purpose. The substitution was made to simplify operation in the field.

Pictures of the WAC CORPORAL show a blister running along part of its length. The blister is a fairing which covers the pipe lines running forward from the air tank, and aft from the propellant tanks (see cut-away sketch of the WAC CORPORAL).

The propulsive system was started by the operation of a device known as an inertia valve, incorporated in the compressed-air circuit. When the booster accelerated the missile out of the launcher, the force of inertia automatically opened the valve, which transmitted air pressure, at one and the same time, to the propellant tanks and to the actuating piston of the main propellant valve.

Fitted into the nose of the WAC CORPORAL, in addition to meteorological instruments, were parachute and automatic devices for releasing both the entire nose cone and the parachute; an arrangement that recommended itself if the instruments installed were to be recovered intact.

The Booster: The booster planned originally to accelerate the missile proved to be inadequate. Substituted for it was a modification of the Navy rocket known as TINY TIM. Changes were made in the fins and nose and thrust was increased. Designed to deliver thrust of 30,000 pounds for one second, the rocket was modified to deliver 50,000-pound thrust for little more than half a second.

Calculations indicated, however, that in little more than half a second the booster and missile would rise some 216 feet, a prohibitive height for a launching tower. It was decided, therefore, to retain a tower height of 100 feet, the height agreed upon earlier to meet specifications as planned originally. Design had to allow, then, for part of the boost to take place in free flight, unguided by the launching tower.

Earlier experience with the PRIVATE A had taught much about the technique for coupling booster and missile in close contact for the duration of a boost, and about the automatic release at the end of the period. Experiments with the one-fifth scale BABY WAC had confirmed the design chosen for the contact-release mechanism, not to mention the fact that a 100-foot tower was high enough.

The Launcher: The launcher, fabricated of structural steel, was a triangular tower 102 feet high, with three launching rails set 120° apart, providing an effective length slightly more than 80 feet, after allowance for the height of the tower base. Piping was attached to the launcher for servicing the missile with propellants and compressed air. A Field Service Trailer, developed by Aerojet for the Navy, simplified the handling of the propellants.

A bomb-proof control house, erected approximately 500 feet from the launching tower, housed measuring instruments and fire control and communication equipment.

The Tests: Firing tests of the WAC CORPORAL were carried out at the White Sands Proving Grounds, Las Cruces, New Mexico, between September 26 and October 25, 1945. Tracked by radar the missile reached, as reported, an altitude of about 43.5 miles in vertical flight. The great increase in altitude over that planned in preliminary estimates was the result primarily of reduction in weight achieved by changes and improvements made as the design matured, and of the added impulse provided by the TINY TIM rocket adopted as a booster.

The Ordnance Department acted as coordinator for the various organizations involved in the development and firing of the missile. The ORDCIT Project was responsible for the preparation of each round for firing, and for the technical phases of the firing program. The Signal Corps, beside providing weather data, provided the equipment for tracking and for receiving signals from radio sonde sets released from the missile. The Aberdeen Ballistic Research Laboratory installed and operated five special camera units and three radar stations located at strategic points around the launcher.

So much, then, about the missiles already completed and tested under the ORDCIT contract.

Remote Control and the Transmission of Flight Data

As part of the ORDCIT Project, the Laboratory is at work upon a system designed for the remote control of guided missiles; and upon two systems for transmitting to ground stations data from vehicles in flight.

Autopilot: A guided missile, the German V-2, for example, is one stabilized by fins and guided, or controlled, by movable surfaces. The automatic system that controls these movable surfaces is called an autopilot.

The Sperry Gyroscope Company, in consultation with the Jet Propulsion Laboratory, has designed and developed an automatic pilot for the control of forthcoming guided missiles. It utilizes three gyroscopes to control, respectively, angle of flight, veering off course, and roll. Whenever the rocket veers from its predetermined course, the gyroscopes signal small motors, one mounted on each of the four fins that stabilize the missile. The tail end of each fin is a movable segment or rudder, controlled by a motor. The action of these rudders keeps the missile on its course.

The gyroscopes, the amplifiers for the signals, and the motors are operated pneumatically, and the compressed air comes from the same tank that supplies pressure to the propellants.

This control system has been designed, not to meet service requirements, but as a means to study control problems. The position of the missile in flight will be plotted by radar, recording the trajectory in both horizontal and vertical planes so that deviations will be apparent. A radio link will be provided for an operator on the ground to signal corrections to the missile, which automatically will apply them. All the control equipment is to be mounted in the nose cone of the missile.

Telemetering: Certain instruments installed in a missile take critical measurements of its behavior in flight. These measurements are relayed to the ground by radio. Application of such a system is known as telemetering, or measuring at a distance. It is planned to report ten quantities continuously to a ground station during flight. The quantities will be the following: angular rates about each of the three axes of the missile, position of each of the control surfaces (rudders), hinge moment on one control surface, longitudinal and transverse acceleration.

The telemetering system developed operates by making each mechanical quantity the frequency-controlling element of an audio-frequency oscillator. Thus, variations in the quantity to be measured result in variations of the audio frequency. Five such audio oscillators of different frequencies are then made to modulate a radio-frequency carrier operating at a frequency of about 100 megacycles. At the ground station the five frequencies are selected by suitable filters, passed into frequency-sensitive circuits and recorded on graphic recorders. The complete ten-channel system consists of two five-channel groups using slightly different radio frequencies. The two transmitters use a common antenna projecting from the nose of the missile.

RAFT (Rocket Air Foil Tester): The RAFT is a rocket designed to fly model airfoils (airplane wings) and to record their aerodynamic characteristics. This method for obtaining aerodynamic characteristics is an important supplement to wind-tunnel tests, which in certain speed ranges are unreliable.

A model airfoil to be tested by the RAFT is attached to a beam protruding from the nose of the rocket. Inside the nose, the beam is supported at three points. At these points, the aerodynamic forces acting upon the model produce pressures, which are measured by strain-gauges.

The strain-gauges for the RAFT are a magnetic type that operates by simple electronic circuits. The gauge is made the frequency-controlling element of an audio oscillator. The measured frequency at the ground station then measures the required force. The radio transmitter used to carry the information from the strain-gauge operates at about 60 megacycles. By insulating the nose of the rocket from the motor, the complete rocket is made to act as an antenna, somewhat less than a half wave-length long.

The RAFT employs a fin-stabilized aircraft rocket, five inches in diameter. Known as the HVAR, it was developed by the NDRC at the California Institute of Technology. Adapted for use as a RAFT, the rocket has a special head.

V. INVESTIGATION OF LIQUID-PROPELLANT ROCKET SYSTEMS

Facilities for Research

Test facilities include seven concrete test pits located at the Laboratory proper, and one special test station at the AAF Muroc Flight Test Base. Each of the Laboratory test pits is capable of handling rocket units with thrusts up to 2,000 pounds; and each is equipped with tanks for handling propellants under pressure, and with an explosion-proof observation room for operators and engineers. At present one pit is devoted to testing a propellant of the liquid-oxygen type, one to hydrogen peroxide, two to a nitromethane propellant, and three to the nitric acid-aniline propellant. The large test station at Muroc is designed for testing motors up to 20,000-pound thrust, for durations somewhat longer than one minute. A motor of this size consumes propellant at the approximate rate of three tons per minute.

One concrete test pit at the Laboratory is devoted principally to the study of pump feed systems for propellants. In this pit is also installed an experimental turbine wheel for pump power supply. It is driven by a device, similar to a rocket motor, which generates gas from propellant liquids.

Other test pits are assigned part time to the study of gas-generating devices both to drive turbines and to pressurize propellants.

Each pit for testing liquid rockets is equipped with instrumentation for measuring motor thrust, the pressure in the reaction chamber, the rate of consumption of propellant, various temperatures, and other quantities of interest. Data are recorded automatically, and the results of each experimental run are reduced by a staff of computers.

Research

A brief review of the research the Laboratory is conducting in the further development of liquid propellant rocket systems may be presented in three parts.

Motors: The purpose of continued investigation of liquid motors is to improve their performance, to discover better methods for cooling them, and to lengthen their service life.

The propellant used essentially determines the maximum performance of a liquid motor. But how closely this limit is approached depends markedly upon the type of injection device used and upon the geometrical configuration of the combustion chamber. Each propellant presents its own set of problems to be solved. A typical acid-aniline motor, for example, gives about 90 per cent of the jet velocity calculated theoretically.

Most motors today are cooled by the propellants themselves which carry away, through the chamber and nozzle walls, the heat transferred by the hot gases of combustion. A promising technique now being investigated is the protection of the inner chamber wall with a film of liquid which evaporates and thus absorbs the heat that otherwise would be transferred to the motor walls. This method is commonly referred to as film cooling.

Research devoted to extending the service duration of several types of liquid-propellant rocket motors has been fruitful. The acid-aniline rocket motor, which the Laboratory has worked on longer than any other, is the most highly developed. Acid-aniline motors of 1500 pound thrust, with a thrust-weight ratio of 30 to 50 have a service duration which can be measured in hours.

A 200-pound thrust motor utilizing a nitromethane monopropellant has operated repeatedly for five-minute periods. The jacketed motor is cooled by the flow of the propellant through the jacket. At present data are being accumulated on the characteristics of motors designed to utilize as oxidizers hydrogen peroxide and liquid oxygen.

Propellant Flow Control: The Laboratory is developing at present lightweight valves to control the initial flow of propellants with great precision. If flow is not predetermined exactly, quantities of propellants, with their violent chemical reactions, may accumulate within a combustion chamber with disastrous effect.

Propellant Feed Systems: Liquid propellants must be fed to the combustion chamber of a rocket motor under pressure. Several methods are available for the purpose, depending upon the specific requirements of the propulsion system in question. The Laboratory is investigating many of them.

Gas pressure will often serve the purpose if the thrust required is of short duration; but when thrust is required for longer periods, the weight and bulk of a pressurized gas become a serious limitation.

The Germans, after a considerable period of development, replaced gas pressure tanks with a system, incorporated in the V-2, which is called a turborocket. The system supplies pressure to the propellants by means of light centrifugal pumps. A turbine operates the pumps, and is driven by exhaust gases generated in a special combustion chamber.

Still another system to supply pressure for propellants is to produce gases from chemicals installed in the missile for that express purpose. This system gives promise of being lighter in weight than any other. The Laboratory initiated studies on it more than a year ago.

VI. THE SEARCH FOR MATERIALS

Need and Facilities for Research

Other things being equal, the higher the heat of combustion in a rocket motor, the higher the exhaust velocity; and the higher the exhaust velocity, the lower the propellant consumption. In their present state of development chamber temperatures of motors utilizing aniline and nitric acid are in the range from 3500° to 5000°F. The reaction of gasoline and liquid oxygen may produce temperatures as high as 6000°F. The numerical values of heat released in such reactions are at least ten times greater than the maximum values encountered in modern furnace practice.

With motor walls of aluminum or stainless steel, the propellant may be utilized to absorb the heat rejected to the surface, even when the temperature developed inside the motor is approximately 5000°F. On the other hand, no material has been found to withstand the hottest flame obtainable with some propellants. Further improvements in the performance of rocket motors, therefore, require either the discovery of new materials to withstand high temperatures or else further development of known ones.

The Laboratory has assembled complete equipment for research in the field of temperature-resistant alloys and ceramics. Six electric furnaces for the heat treatment of metals and for the firing of ceramic pieces have the capacity to handle full-sized units, not merely scale models. Temperatures ranging from 1400°F to 3500°F are obtainable in any atmosphere, and still higher temperatures are obtainable for special studies and to determine melting points. An induction furnace is available for melting and casting alloys.

For research in the relatively new field of powder metallurgy, the Laboratory has an hydraulic press with a capacity of 1800 tons. Equipment is on hand, also, to test accurately various properties of materials as follows: density, porosity, melting point, strength at moderate and high temperatures, thermal expansion and conductivity, resistance to thermal shock and impact strength. The physical structures of alloys and ceramics are studied both by the microscopic method and by that of X-ray diffraction.

<u>Research</u>

As the result of research conducted by the Laboratory, valuable improvements have been made in a chrome-plated copper nozzle designed for rocket motors utilizing nitric acid and aniline. Suitable non-corrosive bearing materials have been found for pumps utilizing nitric acid. Temperature-resistant alloys have been used successfully to construct a cooled liquid-propellant motor with a thin, hence lighter, shell. Tests of ceramic liners for rocket motors are yielding encouraging results.

Ceramic materials, it is anticipated, will play an important part in future developments because they have such high melting points. But because they are brittle and crumble easily, probably they will be used in conjunction with metals rather than replace them. Several methods for producing a bond between ceramics and metals are being investigated. By means of techniques employed in powder metallurgy, a composite material made of layers of metal and ceramic already has been obtained.

At present materials are being developed for uses as follows: liners for chambers of liquid-propellant rocket motors; heat and erosion-resistant materials for exhaust nozzles; porous liners (metal or ceramic) for chambers and nozzles of liquid motors, through which a propellant may be injected to act as a cooling medium; ceramic materials for a turbojet unit, including ceramic turbine blades.

VII. RESEARCH ANALYSIS

The importance of theory in the development of jet propulsion cannot be overemphasized. In the early stages of all such developmental work, knowledge is meager. The systematic way to acquire it is through the interplay of theory and experiment. First, a problem is attacked theoretically. Then the initial solution is applied experimentally. The data thus collected are used in turn to correct or refine the theory. Frequently the cycle must be repeated several times before the desired knowledge is acquired.

The section of the Laboratory devoted to research analysis is responsible for carrying out the theoretical analysis of many problems arising in the field of jet propulsion, particularly those requiring the application of advanced mathematical techniques for their solution.

Solutions are required by many sections of the Laboratory to assist in the guidance of their experimental programs. The armed forces, also, through their inquiries, have suggested problems with regard to possible applications of jet propulsion.

Information requested falls within two categories; information to determine whether or not a new rocket type or a new application for an established one is feasible; and information prerequisite to the solution of specific problems in design. The first category was in demand, for example, when the Ordnance Department requested the Laboratory to examine the feasibility of high-altitude rocket to carry meteorological equipment; the second type, when the engineers began their design study of the forthcoming missile.

Another example of research prerequisite to the solution of a specific problem in design was a method to determine the aerodynamical force exerted against the surface of a missile whenever it veers even slightly from its predetermined trajectory. Applied to the WAC CORPORAL, the calculated results, within the limits of experimental accuracy, checked against the data supplied by tests of a model in a wind tunnel. Thus, the application of theoretical methods to determine aerodynamic forces may often be substituted for expensive wind-tunnel tests.

A great many theoretical calculations of missile trajectories also have been made. For example, the expected trajectories of the WAC

CORPORAL were computed to provide the data necessary for the design of the aerodynamic control surfaces. Another trajectory study was made to determine the feasibility of the WAC as an anti-aircraft missile.

VIII. THE GRADUATE COURSE IN JET PROPULSION

At the request of the AAF Materiel Command, three years ago, a course in Jet Propulsion was instituted at the California Institute of Technology by the staffs of the Guggenheim Aeronautical Laboratory and the Jet Propulsion Laboratory. The course has been limited to officers of the Army and Navy assigned for graduate study at the California Institute of Technology. However, provision has recently been made to open the course to a few especially-selected civilian students.

The course covers the basic principles of all known jet-propelled power systems, and the performance of jet-propelled devices. The Laboratory offers the students first-hand experience with working models of various types of power systems.

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FRANK E. GODDARD, JR.
Assistant Director NASA Relations
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Dr. Goddard was born in Fall River, Massachusetts, on April 18, 1915. He attended the public schools in Attleboro, graduating from Attleboro High School in 1933. He enrolled at the Massachusetts Institute of Technology in 1933, receiving his B.S. degree in aeronautics four years later.

After graduation he became associated with the Consolidated Aircraft Corporation in San Diego, California, as an aerodynamicist. He was associated with Consolidated until 1940 at which time he joined the Glenn L. Martin Company of Baltimore, Maryland, as head of the Aerodynamics Research Group.

After seven years with Martin, Dr. Goddard accepted the post of staff engineer in the Naval Supersonic Laboratory at the Massachusetts Institute of Technology. He joined JPL in 1949 as chief of the High-Speed Wind Tunnel Section.

In his present capacity as chief of the Aerodynamics and Propellants Department, he is responsible for the JPL program in aerodynamics research and high-speed wind tunnel operation, basic research and development in solid propellants, and instrument development and operation of the Lab's large-scale computers.

Dr. Goddard received his Ph.D. in aeronautics from Caltech in 1957.

He is an Associate Fellow in the Institute of the Aeronautical Sciences.

Dr. Goddard lives with his wife, the former Jane Clark Thornton, and son, Stephen, at 2861 Santa Anita Avenue, Altadena, California.

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WILLIAM HAYWARD PICKERING

Director, Jet Propulsion Laboratory
California Institute of Technology

Dr. Pickering was born in Wellington, New Zealand, on December 24, 1910. He spent most of his youth in Wellington, graduating from Wellington High School in 1927.

A year later, after enrolling in an engineering course at Canterbury College, University of New Zealand, a visiting uncle, Horace Douslin -- a civil engineer residing in Southern California -- persuaded young Pickering to return with him to the United States to study.

Dr. Pickering entered the California Institute of Technology in March, 1929. He received his B.S. degree in 1932, his M.S. degree the next year, and his Ph.D. in physics in 1936. He then joined the Caltech faculty as an Instructor in Electrical Engineering. He was appointed Assistant Professor in 1945, Associate Professor in 1945, and Professor in Electrical Engineering in 1947.

Meanwhile, he was deep in cosmic ray research with Dr. Robert A. Millikan, Nobel Prize winner. They travelled to the far spots of the world to study geographical variation of cosmic ray counts, such as India and Mexico, sending balloons to great altitudes. During World War II, in addition to his teaching duties, Dr. Pickering conducted studies of Japanese balloon warfare.

In 1950, already associated with JPL for six years, he was made responsible for the development of the U.S. Army's CORPORAL, America's first long-range liquid-propelled supersonic guided missile capable of tactical application. The culmination of this project occurred in 1954 when completely equipped and trained CORPORAL battalions were sent to overseas stations, thereby broadening the security perimeter of the nation.

Dr. Pickering was appointed JPL Director in 1954, when the laboratory had a staff of 1047. Today, JPL employs some 2300. He heads a team of professional and technical personnel whose mission, until recently, was threefold: 1) To originate, develop and test new guided-missile systems. 2) To conduct supporting research investigations in the physical sciences for the purpose of acquiring basic data applicable to the varied aspects of weapon-system development. 3) To undertake feasibility and evaluation studies of proposed and/or previously initiated programs of special interest to the Nation. With transfer of JPL to the National Aeronautics and Space Administration, JPL's talents are now being reoriented towards space vehicles and missions.

In November, 1957, JPL was given, together with the Army Ballistic Missile Agency, the assignment to fire the first U.S. earth satellite. This assignment was carried out with the successful launching of Explorer I on January 31, 1958. Two other Explorers were later put into orbit by the JPL-ABMA team.

Dr. Pickering was a member of the Scientific Advisory Board, United States Air Force, from 1945 to 1948, and has served on a number of other

(more)

committees of the Defense Department. He is a member of the U.S. National Committee's Technical Panel on the Earth Satellite Program and is Chairman of its Working Group on Tracking and Computation.

He is a member of the American Institute of Electrical Engineers, a Fellow of the Institute of Radio Engineers, and a Fellow and a member of the Board of Directors of the American Rocket Society.

Dr. Pickering received the 1957 James Wyld Memorial Award of the American Rocket Society; a special award by the Los Angeles Chamber for Creative Achievement in 1958; a Scientific Achievement Award from the Greater Los Angeles Chapter of the Association of the U.S. Army in 1958; and the 1958 Institute of Radio Engineers Award of Professional Group on Reliability and Quality Control (PGRQC). Thus far in 1959 he has received the Distinguished Civilian Service Medal; and the first Space Flight Achievement Award presented by the National Missile Industry Conference.

Dr. Pickering became a U.S. citizen in 1941. He lives with his wife, the former Muriel Bowler, and two children, William, 19, and Ann, 16, at 2514 Highland Avenue, Altadena, California.

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DR. EBERHARDT RECHTIN

Chief, ~~Guidance Research Division~~ Telecommunications Div.
Jet Propulsion Laboratory
California Institute of Technology

Born in Orange, New Jersey, on January 16, 1926, Dr. Rechtin spent most of his youth in Pennsylvania and New York. When he was 15, his family moved to California where he graduated from Redondo Union High School in 1943. Honors: Bausch Lomb, Science Talent Search Winner.

He entered the California Institute of Technology in 1943, under the U. S. Naval Reserve V-12 Training Program, and in 1946 he received his B. S. degree in Electrical Engineering. After six months as an Ensign at the U. S. Naval Base in Newport, Rhode Island, Dr. Rechtin resumed his studies at Caltech where in 1950 he received his Ph.D. Cum Laude in Electrical Engineering and Physics.

He became associated as a research engineer with JPL in 1949, specializing in succeeding years in range instrumentation, missile radio guidance, secure communications, information and filter theory, and extreme range communications (Explorer Microlock, Pioneer Trace). As Chief of the Guidance Research Division and deputy director of the lunar probe programs, he is responsible for direction of much of the JPL effort in space communications and tracking.

(more)

Dr. Rechtin is a senior member of the Institute of Radio Engineers and a member of Sigma XI and Tau Beta Pi. He received the Westinghouse Talent Award in 1943 and was designated a Cole Fellow in 1947 and a National Science Fellow in 1948. He is also Deputy Chairman of the Avionics Panel of the NATO Advisory Group on Aeronautical Research and Development.

He lives with his wife, the former Dorothy Denebrink, and three children at 1397 Wicks Road, Pasadena, California.

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WALTER K. VICTOR

CHIEF OF THE COMMUNICATIONS SYSTEM SECTION

Jet Propulsion Laboratory
California Institute of Technology

Mr. Victor was born in New York in 1922. He attended the University of Texas where he received a B. S. in Mechanical Engineering in 1942.

Prior to his military service, he was with the Sperry Gyroscope Company, working on air-borne computer and fire control systems. During the was he served with the Air Corps as a twin-engine pilot instructor.

Mr. Victor has been associated with the Jet Propulsion Laboratory since September, 1953. Currently, he is Chief of the Communications System Section.

He is a member of the honorary engineering fraternity Tau Beta Pi.

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ALBERT ROACH HIBBS
Chief, ~~Research Analysis Section~~ Space Sciences Division
Jet Propulsion Laboratory
California Institute of Technology

Dr. Hibbs was born in Akron, Ohio, on October 19, 1924. He spent most of his youth in Cincinnati and Chillicothe, graduating from Chillicothe High School in 1942. He entered the California Institute of Technology in the fall of 1942 and received his B.S. degree in physics three years later.

Following about a year of active duty as an Ensign in the U. S. Navy, Dr. Hibbs enrolled at the University of Chicago, receiving his M.S. degree in mathematics in 1948.

He joined JPL in 1950 and shortly thereafter entered the graduate department at Caltech, receiving his Ph.D. degree in physics in 1955.

Dr. Hibbs, in his capacity as Chief of JPL's Research Section, is responsible for missile aerodynamics, flight mechanics, and preliminary analysis.

He is a member of the American Physical Society, the American Institute of Physicists, and Sigma Xi. Dr. Hibbs was selected as one of the five Outstanding Young Men of the Year by the California Junior Chamber of Commerce in 1958.

He lives with his wife, the former Florence Pavin, and two children at 969 Shelly Street, Altadena, California.

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JOHN D. MC KENNEY

DIRECTOR, PLANNING STAFF
Jet Propulsion Laboratory
California Institute of Technology

John D. McKenney is Assistant Director, Planning Staff at JPL. In this capacity he is responsible for plans as to how the capabilities of the personnel and facilities of the Laboratory should be employed in the future to best serve the National Space Program and to increase the general effectiveness of the Laboratory. Mr. McKenney joined the Laboratory in 1948. He was assigned to work on the Corporal Project and later was appointed Acting Chief of the Liquid Propulsion Division. The 35 year old engineer is a graduate of Caltech.

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DR. MANFRED EIMER

CHIEF OF THE RESEARCH ANALYSIS SECTION
Jet Propulsion Laboratory
California Institute of Technology

Dr. Eimer, 33, was born in Vienna, Austria. He was educated at the Robert Hammerling Real Gymnasium in Vienna, attending classes there from 1935 to 1938, when his family moved to the United States.

He resumed his education in the United States, attending Mount Vernon Junior High in Los Angeles and Dorsey High School, also in Los Angeles. In 1944, he received a B.S. from the California Institute of Technology and subsequently received an M.S. and Ph.D. from Caltech.

At JPL, he is Chief of the Research Analysis Section. In the satellite firings, he has been concerned with furnishing early orbit determination and in supervising the JPL range safety program.

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ROBERT JOSEPH PARKS
Director, Sergeant Program
~~Chief, Guidance Department~~
Jet Propulsion Laboratory
California Institute of Technology

Mr. Parks was born in Los Angeles on April 1, 1922. He spent his youth in the Los Angeles area, graduating from Newport Harbor Union High School in June, 1940. He enrolled at the California Institute of Technology in September, 1940, and was graduated from that institution with a B.S. degree in Electrical Engineering in 1944.

Following graduation, he served with the U. S. Army Signal Corps for 2 1/2 years, eight months of which were spent with the Occupation Forces in Germany.

After his discharge as a First Lieutenant in July, 1946, he was associated briefly with Hughes Aircraft Company in Culver City, California, as a radio engineer, before joining JPL in April, 1947.

In his present capacity as Chief of JPL's Guidance Department, Mr. Parks heads the group whose mission is guidance and electronics research and development of missile guidance systems, and communications and tracking.

He is JPL's Project Leader for the U. S. Army's SERGEANT, described by military experts as "America's first truly 'second generation' surface-to-surface tactical missile." The SERGEANT

(more)

eventually will replace the CORPORAL, which was also developed by JPL and which is the nation's only operational surface-to-surface tactical ballistic guided missile.

He is a member of the Institute of Radio Engineers, Tau Beta Pi, and Sigma Xi.

He is married to the former Hanne Richter, whom he met while serving with the Army in Germany. They live with their three children at 425 Noren Street, La Canada, California.

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CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

JPL, NASA RESEARCH FACILITY,
DESCRIBES PARKING ORBIT TECHNIQUE

For P.M. Papers
October 12, 1959

Langley Research Center, Va., October 12-- Details of an ingenious new plan to circumvent the undesirable geometrical aspects of launching space probes from the Atlantic Missile Range were described here today at the Annual Inspection of the National Aeronautics and Space Administration at Langley Research Center.

The new plan-- called a parking orbit-- was revealed at the Vega exhibit of the California Institute of Technology Jet Propulsion Laboratory. JPL is a research facility of the NASA.

JPL speakers at the exhibit said the parking orbit technique, long discussed by space experts as a means of increasing payload weights, was refined and suggested for the Vega project by Krafft Ehricke of Convair Astronautics. Ehricke also gave the procedure the name of parking orbit.

It was displayed in an animated sequence at the JPL exhibit, one of eleven such exhibits displayed by NASA laboratories in a week-long demonstration of research now going on in space and aeronautics at NASA facilities.

While the display emphasizes the advantages that accrue to lunar missions from a parking orbit, the technique also has important applications in interplanetary assignments, it was pointed out.

In the past, the JPL exhibit pointed out, the time available in which to launch from the Atlantic Missile Range has been sharply circumscribed to the few days each month that the moon is at its most southerly point in its orbit around the earth.

If it were possible, the JPL exhibit pointed out, to pick up the AMR and move it to a more ideal location, say south of its present position, the geometrical requirements between the earth and the moon could be more easily met, payload weights could be increased and launching times would not be so sharply restricted.

"A launching pad is, by nature, immobile," the JPL commentators said. "But a rocket is by nature mobile. The question is, then: can one use the mobility of the multiple stage space vehicle to compensate for the geometrically undesirable position of the launching pad?

"The answer is: Yes, by putting the second stage of a three-stage Vega vehicle in a parking orbit."

The JPL exhibit then describes how the Atlas booster used as the first stage of the Vega hurls the second and third stage into the start of an earth orbit at satellite speeds.

When the second stage is over that point above the earth's surface which represents the ideal launching place for a lunar mission-- half-way or three quarters of a way around one earth orbit-- the third stage is fired and heads for the moon.

In the lunar mission described in the JPL exhibit, the third stage is fired over Woomera, Australia. The JPL commentator summed it up this way:

"In effect, what occurs is that we place the second stage over that part of the earth where we would have liked to have had the Atlantic Missile Range, and we have fired from that point."

"You ask yourself: is the benefit worth the trouble involved?"

"Let's look at the increases in payload weight made possible by a parking orbit. All other things being equal, a parking orbit provides a 20 per cent increase in payload over a direct ascent trajectory to the moon. This is indeed a large return when one considers to what lengths engineers will go to increase payload weight by only one per cent."

In addition to describing the parking orbit, the JPL exhibit furnished new details about the Vega vehicle, first in a series of new space exploration vehicles being developed for the NASA.

"Vega was initiated by the NASA to provide a space research vehicle capable of launching significant earth satellite and deep space payloads at the earliest possible time," the JPL team said.

"Vega has a capability of placing several tons of payload on orbit around the earth and is capable of deep space payloads of from one quarter to one half ton. As currently envisaged, Vega will provide a continuing space science research vehicle for some years to come, through normal growth and development.

"The first stage of Vega is an Atlas ICBM, provided by Convair Astronautics, modified to accommodate larger upper stages than are presently used. The second stage consists of propellant tanks fabricated from Atlas tank components and a modified General Electric engine. For missions requiring a high velocity increment, such as deep space probes or high altitude satellites, a third stage propulsion system developed by JPL will be used. In addition to developing the third stage, JPL has technical direction of the Vega project.

"The Vega program has the capability of performing these missions: earth satellites in high circular orbits to make meteorological observations; earth satellites to act as communication relays; lunar probes to be flown near the moon on a single pass; lunar probes to be put in orbit around the moon for long term observation of the lunar surface and environment; planetary shots directed as near misses at Mars and Venus.

"Vega will be the first three stage, liquid fueled, fully guided vehicle developed in this country. The second stage General Electric 405H-2 engine has the capacity to be restarted after it is stopped. The third stage engine is a storable liquid using nitrogen tetroxide as the oxidizer and hydrazine as the fuel.

"The fuel and oxidizer are pumped into the combustion chamber by a simple cold helium pressurization system. This is the first practical application of nitrogen tetroxide and hydrazine in a propellant system. It is a combination which offers the highest performance, together with a high degree of reliability, of those available for storable systems. It delivers a thrust of 6000 pounds."

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FOR RELEASE ON DELIVERY

Approximately 10:00 A.M.

Wednesday, March 30, 1960

Statement by Dr. William H. Pickering, Director, California Institute of Technology Jet Propulsion Laboratory, March 30, 1960, to the House Committee on Science and Astronautics.

Mr. Chairman and members of the Committee:

I am grateful for this opportunity to discuss with this Committee the changes proposed to be made in the Space Act of 1958. I do not think I am overstating the case when I say that satisfactory solutions to some of the problems facing us in this area are central to the welfare of this country. We must recognize that the United States is firmly engaged in a space program. We are in space and will be for years to come. Certainly the actions we take now and in the next few years will have an ever widening effect on the character of the program the United States pursues in the exploration of the universe.

Why Space

It seems to me that such problems as exist stem from a complex of causes. First, there is the fact that the U.S. space program is not simply a scientific undertaking to explore space. It has an importance that exceeds the scientific motivation, and indeed we have seen recently that our space program is becoming an instrument of national policy.

Secondly, the space program is being conducted by two agencies, the National Aeronautics and Space Administration and the Department of Defense. Each agency has clearly stated roles, one in the military application and the other in the scientific-Cold War application. Yet, there is some evidence that the two agencies do not fully agree on their respective roles.

Finally, the space program is enormously expensive. Having said this, it is transparent that duplication of effort, waste of talent and resources and marginal programs cannot be tolerated. In this costly new field, with a wide variety of exciting and tempting tasks to perform, one must exercise great moderation to choose and pick within the framework of our ability at the moment, so that a relatively few assignments are performed well. The alternative, of course, is that a great number of tasks are performed poorly.

Part of the misunderstanding relating to the space program, it seems to me, stems from a larger problem. This is the increasing importance of the role of technology in U.S. policy making. When we associate science and government, there is a tendency to assume that when we say science we mean military science. There are quite logical reasons for this misunderstanding, but it is important to point out that in these days of the Cold War propaganda, non military science and technology may indeed be as important to the government as military science. I am not saying, of course, that this is an either/or choice; that one must choose non military science in place of the military technology, or vice versa. I am saying that in some of the concern expressed over the space program, we have tended to overlook the value of non military applications.

As a consequence, governmental support of certain scientific and technological activities outside of the Department of Defense may, and indeed, has assumed a major significance. The establishment of the National Aeronautics and Space Administration is an example of the willingness of the government to embark upon a major non-military scientific program.

However, in view of the long history of support of scientific research by the Department of Defense, it is evident that problems may arise if extensive programs are established outside of the Department of Defense, particularly if these programs appear to impinge on the military field.

The Department of Defense indeed can claim credit for sponsoring a major part of our technological advances in the past decade, but on a long term basis it appears to me that we should now try to agree on the value of government support of non military science and technology. When such an agreement is reached, clearly a mechanism to express such support must be developed.

At the present time, of course, the major agencies conducting such work with government support are the National Science Foundation, the National Aeronautics and Space Administration and the National Institute of Health. The Atomic Energy Commission is in a special category since it has a charter calling for "the maximum contribution to the general welfare, subject at all times to the paramount objective of making the maximum contribution to the common defense and security." Consequently, the AEC serves both a military and non-military function.

Some critics of the space program as it stands today have suggested that it should be established under an AEC-type organization. This indeed would serve the purpose of unifying both civilian and military factors in the program, but in view of the large and valuable experience pool existing in the Air Force, it does not seem reasonable to attempt to transfer this capability to another organization. Therefore, I do not believe that the solution to the problem is to extend the charter of the NASA into an AEC-type organization.

In considering possible changes in the Space Act, it seems to me that we should start with an assumption that no major organizational changes should be made. The progress that has been made in the past year, and the status of working plans for the future combines to suggest that the present organization is entirely capable of performing its assignment. To me, the achievement of Dr. Glennan and his staff in organizing, on the run in a new field, in getting together a bold imaginative program in less than two years, is one of the triumphs of men over circumstance. Any major changes in this organization would do nothing but harm.

Consequently, I conclude that the objective of any change should be to assure better working relationships between the NASA and the Department of Defense so that each is free to pursue its own assignments. For example, the abilities and interests of the Department of Defense should be utilized fully, but this should be done through a clear understanding of national goals and a national space program, followed by an assignment of responsibilities in all major areas which is consistent with the interest and ability of the group concerned.

The fundamental distinction between civilian and military objectives should be clear. Among other things, it is clear that the responsibilities for frontier type developments, and for research and development, must continue for the forseeable future to rest with NASA. The problem is to determine the relative proportion of our resources which should be devoted to each area. If this could be agreed upon, I would expect no major difficulties. There is no problem of supporting a major in-house space capability in the Air Force. With the transfer to the NASA of the Development Operations Division of the Army Ballistic Missile Agency and the Jet Propulsion Laboratory, the large government supported space laboratories are now within the NASA.

In order to arrive at a proper national space program, I do feel that a formal coordinating mechanism between military and civilian planning is required. Dr. Glennan has pointed out that effective coordination between the two groups can occur only if there is a close relationship at all working levels. And, I could add, if there is a real desire for coordination. In this I concur, with the added stipulation that such coordination must occur also at the program planning level.

To bring this high level coordination about, I believe it will be necessary to take action above that which the revision of the Space Act suggests.

Undoubtedly, a number of solutions are feasible. One possibility would be for deputies of both the NASA Administrator and the Secretary of Defense to be co-chairmen of a small planning group which establishes programs within policy guidelines laid down by the President. The actual solution is perhaps a matter for Executive action, but the Congress should assure itself that the total national program indeed is coordinated as the spirit of the Space Act demands.

In conclusion, please allow me to express to the members of this Committee, and through you to the Congress, my thanks for the fine support and understanding you have given the national space program. Thank you.

California Institute of Technology

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FOR RELEASE: Sunday, December 25, 1960

Selection of four companies to engage in a four month study designed to investigate the feasibility of an advanced space tracking antenna was announced tod y by the California Institute of Technology Jet Propulsion Laboratory.

JPL is a research and development facility of the National Aeronautics and Space Administration charged with the unmanned exploration of the moon and the planets.

The four companies were selected from 17 which made proposals to JPL on Nov. 7 following a two-day briefing September 29 and 30 at JPL and Goldstone, California, site of the Goldstone tracking station in the world-wide Deep Space Instrumentation facility (DSIF). The selected companies are: Blaw-Knox Equipment Division, Blaw-Knox Company, Pittsburgh, Pa.; Hughes Aircraft Company Ground Systems, Fullerton, California; North American Aviation Inc., Columbus, Ohio, and Westinghouse Electric Corporation, East Pittsburgh, Pa.

Each of the four companies will submit to JPL by late Spring, 1961, a design analysis of a large tracking antenna from 200 to 250 feet. At present, the three DSIF stations at Goldstone, Woomera, Australia and the one being constructed at Krugersdorp, South Africa, employ tracking antennas 85 feet in diameter. If technically and financially feasible, the advanced antennas would increase the DSIF communications capability 10 to 30 times.

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FOR RELEASE Friday a.m., August 25, 1961

Selection of the Blaw Knox Equipment Division, the Blaw Knox Company, Pittsburgh, Pa., to conduct a second phase feasibility study concerning a 240 foot in diameter space tracking antenna for Goldstone, Calif., was announced today by the National Aeronautics and Space Administration. The contract amounts to $250,000.

The announcement was made by Edmond C. Buckley, Assistant Director of Space Flight Operations for the NASA, and Dr. Eberhardt Rechtin, Director of the Deep Space Instrumentation Facility (DSIF) which is operated for the NASA by the California Institute of Technology Jet Propulsion Laboratory.

The DSIF presently consists of three tracking stations, located approximately 120 degrees apart around the world in order to insure that one of the stations always is in position to maintain radio contact with a spacecraft. The stations are at Goldstone, Calif., which is equipped with two space tracking antennas each 85 feet in diameter; Woomera, Australia, and near Johannesburg, South Africa. The Woomera and Johannesburg stations each have one 85 foot in diameter antenna.

While the existing antennas are useful for a variety of space experiments, the larger antennas will permit tracking over much greater distances, Dr. Rechtin explained. In addition, he said, the present DSIF stations are heavily overloaded by the requirements of the lunar program.

Thus, when it became clear that new antennas would have to be added to the DSIF, initial feasibility studies showed that an increase of three times in the size of the 85 foot antennas would probably improve communications by a factor of ten at a cost competitive with alternate solutions involving spacecraft components.

"Although an improvement in communications by a factor of ten would be useful in deep space exploration at any time," Dr. Rechtin said, "this improvement becomes a virtual requirement with the coming of the Saturn class launch vehicles."

"These vehicles are capable of launching spacecraft which can perform missions that were not possible before. Typical of these new missions are lunar roving vehicles, photographic lunar and planetary probes and advanced programs associated with manned flight to the moon."

This phase of the Blaw Knox feasibility and design study is expected to be completed by July of 1962. The planning schedule calls for the 240 foot antenna to be operational at Goldstone by January 1, 1965.

Blaw Knox was chosen from four companies which engaged in a competitive four month initial study to investigate the feasibility of large antennas. These four companies had been selected from 17 companies which made proposals to JPL following a two-day briefing on September 29 and 30 of 1960.

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PASADENA, CALIFORNIA. TELEPHONE MURRAY 1-3661, EXTENSION 3351

FOR RELEASE: February 5, 1962

PASADENA, Calif.--Solution of a long-outstanding mathematical problem was announced today by a three-man team composed of CalTech and Jet Propulsion Laboratory mathematicians.

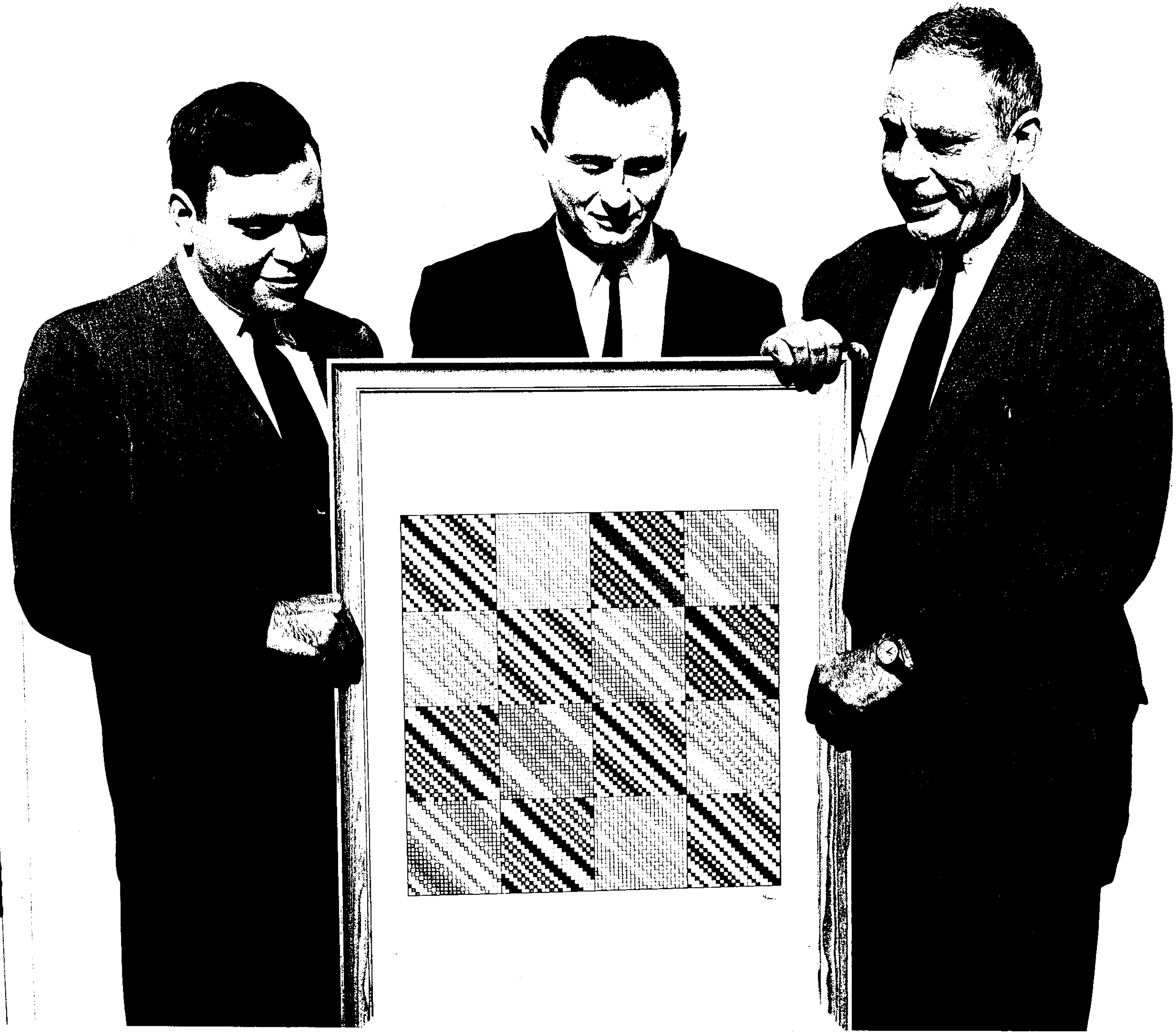
The importance of the discovery for divising codes for space communications was pointed out by Dr. Solomon W. Golomb, assistant chief of JPL's Communications Systems Research Section; Prof. Marshall Hall, Jr., CalTech Mathematics Department; and Leonard D. Baumert, predoctoral student at CalTech, who all cooperated in the solution.

Titled "A Hadamard Matrix of Order 92," the discovery involved construction of a pattern of variable combinations of positive and negative signs (a Hadamard Matrix) consisting of 92 rows and columns. Jacques Hadamard, the great French mathematician, first studied such combinations in 1893. Later scholars, among them R. E. Paley in 1933, described a variety of methods for constructing Hadamard matrices. Of the sizes less than 200 for which a Hadamard matrix could exist, there were only six cases where Paley did not give a solution.

In 1944, another mathematician, John Williamson, succeeded in constructing a Hadamard matrix of 172 columns by 172 rows, thus reducing this list of unsolved sizes to five. Since 1933, many mathematicians had attempted to prove or disprove the existence of a 92 by 92 combination.

"Due to the large number of possible internal combinations," Dr. Golomb stated, "even an electronic computer working at the rate of a million a second, would take billions of years to test all possible solutions of the problem." After useful suggestions by Prof. Hall, the JPL IBM 7090 computer was programmed by L. D. Baumert to search for a solution similar to Williamson's 172 by 172. An example of the long-awaited 92 by 92 Hadamard matrix was discovered after less than an hour of computation. In fact, according to Dr. Golomb, there turned out to be one and only one example of the Williamson type for size 92.

The large square in the photograph presents positive (dark) and negative (white) squares arranged into rows in such a way that between each pair of rows there are 46 positions in agreement (dark and dark or white and white) and 46 positions in disagreement (dark and white).



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FOR RELEASE: Wednesday, p.m., February 14, 1962

PASADENA, Calif.--A new environmental simulator was used for the first time today at the California Institute of Technology Jet Propulsion Laboratory to test the reactions of a spacecraft to a long trip to the planet Venus.

The space simulator, the largest of its kind in the United States, will be used to determine the ultimate design of lunar and planetary spacecraft that JPL is developing for the National Aeronautics and Space Administration.

The first spacecraft in the chamber will be Mariner, a 450 pound Venus probe that will be subjected to the environment of space for 3 weeks. The Mariner is 10 feet high and measures $14\frac{1}{2}$ feet across with its solar panels extended. In this test a full-scale temperature control model is used.

The space simulator, which costs $4 million, was built for the Laboratory by a team of industrial firms headed by Consolidated Vacuum Corporation of Rochester, New York.

The entire facility consists of a 10,000-square-foot building to house offices, a control room, an equipment area, and the space simulator. The simulator is a cylindrical tower 80 feet high and 27 feet in diameter. Contained within the lower part of this silo-like structure is a stainless steel vacuum chamber that measures 47 feet high by 25 feet in diameter for testing spacecraft. The upper part of the tower houses a solar simulation unit.

The advantages of creating here in Earth the conditions that a spacecraft must endure during a three-month space flight to the nearest planets is explained by Herbert D. Strong, Chief of the Wind Tunnels and Environmental

Section at JPL.

"Space is characterized by an absence of heat and pressure," says Strong. "It is a perfect vacuum where temperature, as we know it on Earth, does not exist unless there is some object to intercept the radiant heat from the sun."

Since the only energy in space is that radiated from the sun, the temperature of an object, such as a spacecraft, would depend on several factors: its distance and orientation relative to the sun, its color or finish, the material of which it is made, and its shape.

"A black ball," Strong explains, "would absorb more heat in space than a white ball. If the black ball happened to be made of a material that was a poor conductor of heat, only the side facing the sun would be hot. The other side which faces dark space would be extremely cold."

"In designing something as complicated as a spacecraft," says William R. Howard, Chief of the Engineering Facilities Division, "conditions such as these where there are hot and cold spots can lead to complications. Electronic components would freeze or bake, batteries would stop working and sensitive measuring devices would be useless."

"What we must do," he says, "is design a spacecraft that has the right color, finish, material, and shape to absorb just enough heat to maintain a warm temperature all over. In order to do this a space environment simulator is needed that is large enough to test the complete spacecraft in its flight configuration."

Such a simulator must meet three basic requirements: It has to have a lighting system that duplicates all the visible and invisible rays of the sun in a collimated beam; it has to be as close to the perfect vacuum of space that is practical in a chamber of this size; and it must be designed so that the inner walls do not emit heat, and absorb heat and light rediated by the spacecraft.

A unique feature of the space chamber is the intricate optical system designed by Bausch & Lomb, of Rochester, New York. Artificial sunlight is generated by 131 compact arc mercury xenon lamps. Each lamp utilizes $2\frac{1}{2}$ kilowatts of power and has a 16-inch reflector.

At the outset of the study to develop this optical system, it was suggested that the lights be placed inside the vacuum chamber. However, the initial design analysis indicated that this arrangement would create quite a cooling problem and it was decided to put the system in a space on top of the chamber and shine the light down into the vacuum chamber through a 3-foot lens.

The system works like this: The light from the mercury xenon lamps shines downward on a parabolic mirror and is reflected upward in a concentrated beam to a hyperbolic mirror. From there it is reflected downward again through the lens and into the vacuum chamber. This external light source works similar to the optical system of a Cassegrain telescope.

Once inside the chamber, the 3-foot beam of light has to be widened to about 12 feet. To accomplish this, a special $2\frac{1}{2}$ foot-in-diameter mirror reflects the light beam to a parabolic mirror at the top of the cylindrical chamber. From there it shines down on the spacecraft in a collimated beam, as would actual sunlight in space. Eventually this system will be modified to project a 25-foot beam.

One of the interesting features of this lighting system is that it can be varied to simulate the intensity of sunlight that a spacecraft might be expected to encounter as near to the sun as Venus or as far away as Mars.

At these intensities, a great deal of heat is projected onto a spacecraft travelling in space. If it is well-designed, the spacecraft will absorb some of this heat to keep its thermal balance near the optimum level. The rest will be reflected into the infinity of space.

When a spacecraft is confined in an ordinary vacuum chamber, with room temperature walls, apreciable heat is radiated back into the chamber by the walls, creating a condition unlike space.

To simulate the space environment an aluminum shroud was built inside the JPL chamber. The shroud is made of 200 plates which are dull black to absorb heat and cooled to -310 degrees Fahrenheit. This temperature is maintained by pumping liquid nitrogen through small tubes running through the shroud. With this system, 99 per cent of the heat radiated from the spacecraft is absorbed and carried away. The nitrogen (which boils at -320° F.) is stored in a 28,000 gallon tank outside the new building.

Of course, the higher the solar intensity of the test (depending on whether the spacecraft is designed for a trip to Venus or Mars), the more nitrogen is consumed. Venus receives twice the solar intensity of Earth, and the Earth has $2\frac{1}{2}$ times the intensity of Mars.

To create an adequate vacuum in the chamber a three-stage "pump-down" is utilized. The first stage is accomplished by seven compressors ordinarily used to run JPL's 20-inch supersonic wind tunnel. Then, as this line is valved off, a "roughing" system, consisting of three vacuum blowers, removes all but a small fraction of the initial air. At that point, ten oil diffusion pumps take over to produce a vacuum of 10^{-6} millimeters of mercury, which is about one billionth of the atmosphere at sea level. (The vacuum of space is a billion times less than this.) These diffusion pumps work continuously during tests to remove any outgassing or evaporation from the chamber.

Spacecraft will be placed on a special support in the simulator with the aid of a handling cart. Twelve portholes in the chamber allow observation of the spacecraft during a simulated space exposure.

During a test, engineers in the control room will monitor the reactions to the space environment of the spacecraft's transmitting and receiving equipment, guidance and control system, and scientific instruments. This will be accomplished by electrical circuits which connect to various parts of the spacecraft and lead through the walls of the chamber into the control room.

Another feature of the chamber will be the optional addition of a vibration unit at a later date. This will simulate vibrations that a spacecraft would encounter during mid-course maneuvers or when retro-rockets fire.

While CVC is responsible for the overall design, fabrication, and management coordination of the entire facility, many of the design features were the products of a joint CVC-JPL effort. Melvin N. Wilson, head of the JPL Technical Facilities Group, is the project engineer responsible for the Laboratory's contributions.

Consolidated Vacuum Corporation's design and fabrication team includes the following subcontractors:

Pittsburg-Des Moines Steel Corporation, Pittsburgh, Pennsylvania- Fabrication of the steel vacuum chamber and erection and assembly of the entire facility.

Aetron Division of Aerojet-General Corporation, Covina, California - Design of the building, instrumentation and external cryogenics.

Bausch & Lomb, Rochester, New York - Design of solar simulation system.

Tenney Engineering Corporation, Union, New Jersey - Internal cryogenics and power system for lights.

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FOR RELEASE SUNDAY, JANUARY 9, 1965

PASADENA--Appointment of project managers for the two forthcoming Mariner-series deep space exploration missions to Venus and Mars has been announced by Gen. A. R. Luedecke, Deputy Director of the Jet Propulsion Laboratory of the California Institute of Technology.

Dan Schneiderman, Mariner IV project Manager, will manage the Venus project. It involves a single spacecraft to be launched in 1967. In addition, he will continue through 1967 in the completion of his duties as Project Manager for the recently successful Mariner IV mission to Mars.

H. M. Schurmeier, former Ranger Project Manager and currently Capsule System Manager for the Voyager series, will manage the new Mars project, an effort involving two new Mariner spacecraft scheduled for launch in 1969.

Effective February 1, Schurmeier will relinquish his duties as Voyager Capsule System Manager to Geoffrey Robillard, who will also continue in his present duties as Deputy Voyager Project Manager under Dr. D. P. Burcham, Luedecke said.

Voyager is a planetary exploration spacecraft scheduled for launch to Mars in 1973.

JPL will design and build the two Mariner/Mars '69 spacecraft and modify a spare Mariner IV spacecraft for the Venus mission in 1967.

JPL was assigned project management for the two new planetary missions by the National Aeronautics and Space Administration.

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FOR RELEASE: Sunday, July 10, 1966

Pasadena, Calif.--A solid state battery no larger than the end of your thumb has been developed by three scientists at the Jet Propulsion Laboratory of the California Institute of Technology.

The miniature battery may have wide application in microelectronics circuits used in spacecraft and throughout the electronics industry.

This potential breakthrough in micro-miniaturization was the joint accomplishment of Dr. Allen M. Hermann and Dr. Alan Rembaum of the JPL Polymer Research Section, and Prof. Felix Gutmann of the University of New South Wales, Australia. All of the research was done at JPL, which Caltech operates for the National Aeronautics and Space Administration, reports Dr. Robert Landel, manager of the Polymer Research Section.

The Tom Thumb battery--the size of a dime--has a core of three wafers. The electrolyte can be made from several synthetics known as charge-transfer complexes. The electrodes are of dissimilar metals. One cell which underwent extensive testing was made from iodine mixed with perylene sandwiched between thin wafers of magnesium and platinum. This gave a voltage of 1.5 volts.

When perfected, the cell could be made even smaller, the scientists say. Moreover, the battery may be sterilizable for spacecraft use. Thus far it has withstood tests at temperatures of over 130 degrees, Centigrade (266 degrees, Fahrenheit).

The tiny cells generally produce current of a few milliamperes with a useful lifetime comparable to that of commercially available cells. They can be recharged and have an indefinite shelf-life. According to the inventors, the cells lend themselves particularly well to spacecraft squib-firing mechanisms where a capacitor is charged from a primary power source.

But perhaps their main use may be to energize microelectronic circuits, making spacecraft sub-systems less dependent on the main power supply. Since they are solid state devices of small size, they can be incorporated directly into microcircuits by standard techniques.

The polymeric batteries, in their present state of development, would appear to have limited commercial potential because of the relatively low current generated. However, in one recent test of a charge-transfer complex, a short-circuit current of 25 milliamperes was obtained.

Open-circuit voltage for the iodine-perylene cell may be as high as 2.5 volts depending on the types of electrodes used.

Perylene is a hydrocarbon which, when mixed with iodine or other halogens, forms a charge transfer complex of low impedance. Other complexing agents tested included a promising polymer, poly-N-vinylcarbazole.

While solid state cells have been under investigation for years, the JPL cell is believed to be novel in that the electrolytes are made more conducting by combining with organic substances which are themselves insulators. The cells, therefore, produce correspondingly more current.

The composite electrolytes also are soluble in a large number of solvents, an important feature from a production point of view.

The researchers have also devised and tested a battery containing no metal. The total cell was made from synthetics containing only carbon, hydrogen, and nitrogen. An open-circuit voltage of .15 volts and minute current resulted. Development of non-metallic cells would therefore appear to be of only scientific curiosity at this time.

Advantages of solid state cells over wet cells, or even dry cells, are clear-cut. Wet cells contain inorganic acids as electrolytes. Dry cells are not really dry since they contain ammonium chloride in water.

Aiding in space adaptation, the Tom Thumb batteries should be insensitive to radiation, the developers say.

The basic research leading to this development was supported by NASA's Office of Advanced Research and Technology.

395-6/29/66

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FOR RELEASE: Sunday, October 23, 1966

NEW JPL FACILITY TO ASSURE STERILE VOYAGER TO MARS

PASADENA, Calif.--A new laboratory clean enough to excite the envy of a Dutch housewife may aid United States scientists in achieving the goal of landing a sterile Voyager capsule on Mars in the next decade.

Caltech's Jet Propulsion Laboratory this week announced a $200,000 contract had been awarded to Avco Corporation's Space Division, Wilmington, Mass., for task work in JPL's new $1.5 million Sterilization Assembly Development Laboratory (SADL). Starting in mid-1967, SADL will be sterilization testing headquarters for Voyager, the spacecraft of the 1970's.

In this antiseptic laboratory, JPL research engineers will use sterilizing heat and gas to develop methods that will reduce to an infinitesimally small probability the chance of any live Earth microbe arriving on Mars. The clean-room tests comply with requirements of the National Aeronautics and Space Administration that no U. S. spacecraft should contaminate Mars or any other planet of biological interest.

NASA has designated JPL to conduct the Voyager Project for solar system investigation starting in 1973. The unmanned spacecraft will be designed to fly by, orbit and land survivable capsules on Mars and Venus, with the goal of studying possible life on these planets or the remains of life in the past.

The 1,200-square-foot SADL clean room, 35 feet high, will advance techniques developed since 1964 in a smaller Experimental Assembly and Sterilization Laboratory (EASL) at JPL. The purpose of SADL is to refine sterilization procedures specifically for planetary landing capsules.

First major SADL project will be assembling a 14-foot Voyager capsule model. Electronic sub-systems also will be tested. The capsule will be used as an exercise vehicle for evaluating procedures, improving ways of measuring organisms, and devising the cleanest handling methods before the Voyager is ultimately designed.

George Ervin, Voyager capsule sterilization engineer, estimates it will take several years to fully develop a germ-free capsule. Before the capsule is given its final dry-heat sterilization, it will be sealed in a canister to shield it from possible in-flight contamination. This canister will be discarded prior to entering the Mars atmosphere.

The JPL tests will determine clean-room standards to be required of Voyager contractors. The NASA quarantine plan asks that Voyager's mission be studied for every conceivable source of contamination and that all parts of the capsule be certified biologically sterile--virtually 99.99 per cent pure.

Such quarantine, NASA says, is necessary if Voyager is to take and assay accurate exobiological samples on Mars. From these samples scientists hope to define the Martian biosphere. The biosphere is that part of a planet and its atmosphere capable of sustaining life. Exobiology is the study of living organisms on other planets.

What do scientists expect to find on Mars? With its apparent lack of oxygen, most foresee little chance of discovering higher forms of life there.

"We may find microorganisms, mosses, lichens," hazards Dr. Charles W. Craven, JPL Voyager quarantine manager.

But as Dr. Norman H. Horowitz, chief of JPL's bioscience section, puts it: "Any form of life, however primitive, found on Mars would be of immense scientific value. Studies of the Martian genes and enzymes would tell us whether Martian life originated independently, or is a branch of the same family tree that we have on Earth."

How does JPL achieve 99.99 per cent cleanliness?

The SADL researchers will subject Voyager parts to dry heat cycles and ethylene oxide gas exposures. The current heat treatment for qualifying photo type equipment is at 135 degrees Centigrade (275 degrees Fahrenheit). Qualification for gas exposure is at 50 degrees, C. (122 degrees, F) and 45 per cent humidity. Actual sterilization cycles for flight equipment would be a little less rigorous.

In EASL, components are assembled in laminar air-flow benches set in the walls. In SADL, capsule assembly will be made in the central vertical air-flow clean room.

The heat-gas cycles kill off bacterial spores so that there will be only a very remote probability of even one spore surviving, sterilization engineers report. These spores, among nature's most primitive forms, have proven most resistant to sterilization.

They work in a constant flow of air from ceiling to grated floor, at a zephyr-like one mile per hour. Room temperature is a constant 70 degrees (F), humidity 45 per cent. The air is recirculated through fine filters which remove microorganisms. Thus far EASL has satisfied NASA's requirements and furnishes a solid basis for the SADL clean room.

Besides SADL, nearly a score of NASA-JPL sterilization projects are under way. Among these are decontamination of solid and liquid-propelled rockets, and building an approved list of electronic parts for Voyager spacecraft that will withstand sterilization. Several industries have clean rooms helping JPL run 10,000-hour tests on resistors, transistors, diodes and circuit boards. Current JPL budget on this program alone is $1.1 million.

Sterilization engineers have found that heat seems to break down more parts than gas. Synthetics and soldered connections are most susceptible to heat. When the first Ranger moon spacecraft was sterilized, protective plastics shrank, seals leaked and wire insulation cracked, causing electronic failures.

To prevent such mishaps in the Voyager project, synthetics--polymers in the engineer's lexicon--must be toughened up. The myriad uses of polymers in spacecraft include epoxy adhesives, electronic packaging, thermal insulation and cables. Throughout the project JPL engineers will check contractors to assure NASA that quarantine and quality requirements are being met.

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FOR RELEASE: Sunday, November 13, 1966

JPL MARS BIOLOGICAL TEAM TO STUDY ANTARCTIC VALLEYS

PASADENA, Calif.--A biological team from Caltech's Jet Propulsion Laboratory leaves tomorrow (Monday, Nov. 14) for the first investigation of Antarctica sponsored by the National Aeronautics and Space Administration.

Headed by Dr. Roy E. Cameron, senior soil scientist, the JPL team will spend 2½ months in Antarctica valleys taking samples and conducting tests that may prove helpful in future unmanned exploration of Mars.

Gerald B. Blank will accompany Dr. Cameron. On arrival at McMurdo Sound Nov. 17 they will set up one ton of equipment sent ahead for an Antarctic summer field laboratory.

At McMurdo Sound the scientists will study soils to be obtained from the Wright, Victoria, Taylor and Beacon valleys. Helicopters will drop the men off in these ice-free valleys and scientific measurements will be made for several weeks at various sites.

The investigators hope to find micro-organisms in the frigid, desert-type soil. Measurements also will be taken of temperature, humidity, wind, evaporation, solar radiation and heat exchange.

One ton of soil will be shipped back to the United States under refrigeration for further culture study by JPL and other NASA scientists.

The JPL team will be in Antarctica until Jan. 31, 1967. The investigators also plan to spend ten days doing comparative soil studies in New Zealand before returning home about Feb. 15.

(more)

The Antarctic investigation continues the JPL study of Earth's harshest desert areas. Dr. N. H. Horowitz, JPL bioscience section manager, says such studies are essential before life-detection experiments are sent to Mars in the next decade. Because of its thin atmosphere and scant water, Mars is believed to be largely desert. Detection of extraterrestrial life is a prime NASA concern.

Earlier this year Dr. Cameron and Richard Davies of JPL collected 750 pounds of desert soil samples from the Atacama Desert--believed the world's driest--in Chile. A group of micro-flora (miniature plant life) was found which can grow well with very little oxygen. Tests are continuing on 36 Chilean samples taken from 21 sites from sea level to 20,000 feet.

Extensive preparations have been made for the JPL investigation in Antarctica. For the past five summers, soil studies have been made in the White Mountains of California at elevations of 12,500 to 14,250 feet, simulating alpine-polar sites.

The expedition has the logistical support of the National Science Foundation. Other biologists have found lichens and mosses at sea level in Antarctica, but previous investigations in higher valleys have been sketchy and yielded no microorganisms.

Other institutions which will assist later in the Antarctic study are the University of California at Los Angeles, Oregon State University and New Mexico State University at Las Cruces.

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For Release: A.M.'s Sunday, August 13, 1967

TWO MARINERS TO COMBINE IN NASA-JPL SOLAR PLASMA STUDY

PASADENA, California--The Mariner Venus spacecraft of 1967 may combine with the Mariner Mars spacecraft, vintage 1964, in a novel experiment planned for this summer and fall by Caltech-Jet Propulsion Laboratory scientists for the National Aeronautics and Space Administration.

This month, September and early October before Mariner V is scheduled to fly by Venus, JPL scientists will attempt to get readings on solar plasma and space magnetism from both Mariner V and Mariner IV while they are in the same direct line with Earth and the sun.

The two spacecraft would be about 70 million miles apart with Earth roughly in the middle, on a line drawn from the Sun. The unique lineup could be capitalized on assuming that Mariner IV's radio transmitter would still be operating.

"And we have no reason to believe it won't be," says Conway W. Snyder, Mariner Venus project scientist. The Mars Mariner's signal came through loud and clear only last week on the Caltech-JPL 210-foot antenna at the nearby Goldstone, California, Deep Space Station. At that time Mariner IV was more than 75 million miles from Earth.

From as far as 215 million miles, Mariner IV has reported scientific data to Earth for 2½ years.

Mariner V was launched from Cape Kennedy on June 14 with encounter of the planet set for October 19.

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The periods of conjunction that will be studied are from about August 10 to 21 and roughly September 1 to October 10. On September 7, Mariner IV will be only 29,167,000 miles from the Earth in its elliptical swing, and Mariner V will be roughly 20.5 million miles distant.

By the time Mariner V encounters Venus it will be 49.5 million miles away and Mariner IV, moving slowly, will have fallen behind Earth, 34 million miles out.

The JPL space scientists hope to record shock waves and other disturbances in the solar wind or magnetic fields encountered by each spacecraft during August. The solar plasma streams out from the sun at rates of 200 to 500 miles per second, according to previous experiments on Mariner II and other spacecraft.

Later, during September and October, the two-spacecraft readings will be concerned with concentrations of solar high-energy particles. Attempts will be made to measure the speed and direction of streams of electrons and protons.

These high-energy particles move at almost the speed of light (186,000 miles per second), and hence can travel from Mariner V to Mariner IV in a matter of minutes. The August readings, because of the slower plasma stream, would require up to a day and a half to record.

This would be the most spectacular use of Mariner IV since it flew by Mars on July 14, 1965, and returned 22 pictures of that planet from a distance of 6,118 miles. The time of the projected twin-spacecraft experiments would be nearly three years after the Mariner IV launching on November 28, 1964.

Among the other half-dozen major experiments scheduled to be accomplished by Mariner V are radio occultation measurements of the density and the composition of the heavy Venus atmosphere.

Other instruments will seek data on temperatures, electron density and possible radiation belts around the Earth's sister planet. Scientists also will attempt to obtain more accurate figures on Venus' mass, orbit and general position vis a vis Earth in the solar system. Venus orbits the Sun at a mean distance of 67.2 million miles. Earth orbits at a mean 92.9 million miles.

In sum, the scientific findings of Mariner V could contribute some leading answers--not final, of course, but helpful--to the interesting questions:

How much is our sister planet really like Earth?

What chance is there of finding life on Venus via robot landers?

And, ultimately, would there be any point in sending a manned spacecraft to Venus in the future?

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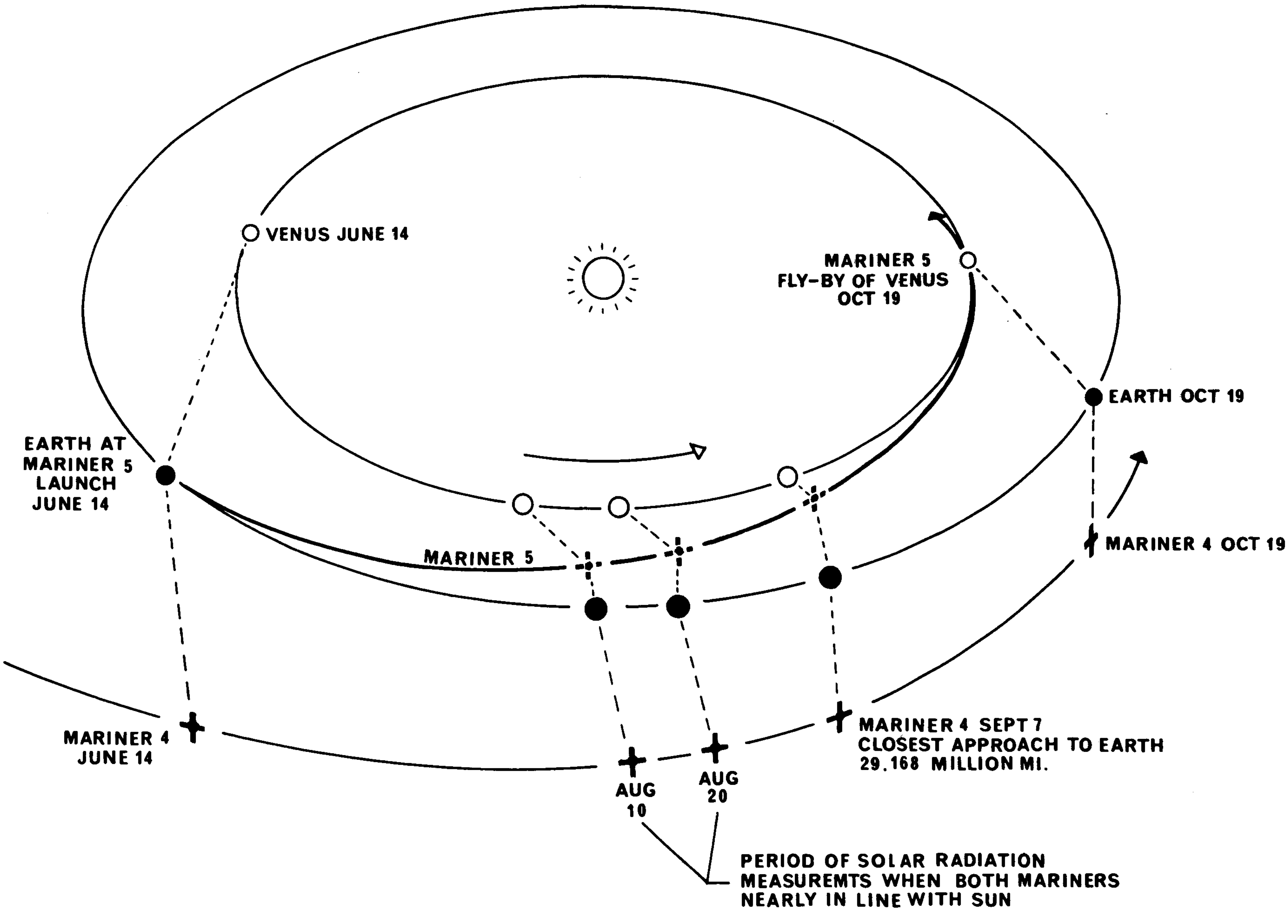
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FOR RELEASE: A.M.'s, Monday, September 4, 1967

CALTECH-JPL SPLIT-SECOND TESTS SIMULATE
HARD LANDINGS ON MOON AND PLANETS

PASADENA, Calif.--In a shattering one-tenth second or less, Caltech-Jet Propulsion Laboratory engineers trigger tests which determine what chance spacecraft equipment has of surviving a rough landing on the moon or planets.

Split-second JPL impact tests, using powerful compressed air guns and a giant slingshot, hurtle equipment against solid backstops at speeds up to 500 feet per second (340 miles per hour).

These experiments have proved that intricate, delicate components required in sophisticated unmanned spacecraft of today and tomorrow can be protected to withstand shocks of 10,000 G's. The G is a unit equal to the Earth's gravitational acceleration.

Stan Taylor, engineer in charge of high impact testing, explains it this way, "During the brief instant that the test specimen is experiencing the 10,000 G shock, every part of it behaves as though it weighed 10,000 times its normal weight. The bolts supporting a one pound test item have to be good for about five tons."

Since 1959 the JPL high-impact program has helped, through testing thousands of pieces of equipment, in formulating stronger design for spacecraft equipment in lunar and planetary projects of the National Aeronautics and Space Administration.

Moreover, continuing tests show present components and designs will not have to be changed radically to withstand relatively hard landings.

"Future planetary missions may impact capsules or instrument packages at speeds of a few hundred feet per second," says Marcus G. Comuntzis, manager of the

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lunar spacecraft development section, which also works on planetary missions. The high-impact program he directs "tells us what causes failure and what must be done to insure survival of a spacecraft."

Comuntzis is talking about unmanned spacecraft. But, he adds, lessons learned in high-impact testing could be helpful in building sturdier manned spacecraft.

All types of equipment undergo the shock treatment--electronic components, transmitters, amplifiers, tape recorders, batteries, motors and mechanical parts. Most of these can be "ruggedized" as well as miniaturized, according to James O. Lonborg, supervisor of the high impact and advanced mechanisms group.

High impact research is conducted in the range from 2,000 to 10,000 G's and speeds of 200 to 500 feet per second (137 to 340 mph).

Tests are designed to simulate braked spacecraft approach speeds to the moon or near planets. Presently, retro-rockets are used to slow down spacecraft before landings; parachutes or balloons may be used in the future. Unbraked approach speeds range from 9,000 feet per second to the moon up to 25,000 F.P.S. to Mars (6,140 to 17,000 mph).

The JPL compressed air guns have bores of 3, 6, 22 inches. The huge slingshot uses two 20-foot rubber strands called bungee to propel the test specimen and its supporting sled down a track at speeds up to 200 feet per second. The impact is "softened" by allowing the steel nose of the sled to penetrate into a copper block. The guns launch specimen-containing projectiles at higher speeds against balsa or redwood backstops to accomplish similar results.

While the slingshot operates above ground in a carefully screened area, the guns have been installed in bunkers to muffle the noise and reduce the dangers of ricocheting.

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The 22-inch gun is housed in a 50-foot bunker with walls 14 inches thick. The gun, resembling a Navy breach-loader, has an 18-foot barrel and a pressure chamber (accumulator) 12 feet long. It is pressurized to a maximum of 200 pounds per square inch.

The test weapon fires an aluminum alloy projectile called a sabot, French for shoe. Weighing over 250 pounds, it packs quite a kick. Up to 100 pounds of equipment can be attached to the sabot.

Fired only eight to 11 feet, the sabot package smacks the redwood backboard with up to one million pounds of force and 500 feet per second velocity. Testers operate the firing controls from a separate bunker. They observe and record each test on closed-circuit television.

A team of testers headed by Stan Taylor recently began a new series with the 22-inch gun. A 260-pound sabot was fired at 275 feet per second into the redwood barrier producing a 7,400 G shock. The backboard, consisting of 49 redwood blocks (6-inch cubes) locked in a frame, was indented to an average depth of 2 inches.

Future experiments will carry the impact range beyond 10,000 G's.

For a young engineer whose equipment is being tested on the smashing block, suspense can be excruciating. In a recent test of a compact 3/4-pound antenna prototype, Dr. Kenneth Woo winced as his "baby" was slung by the bungee at 8,000 G's and 165 feet per second.

The planetary spacecraft antenna was encased in a 9-pound aluminum box riding between steel runners. The linen-wrapped rubber bands were pulled taut by an electrically-controlled cable.

When the control button was pushed, the box was snapped 17 feet in roughly a tenth of a second. The whang of the impact was almost instantaneous. The protective steel prong on the front of the box was driven almost an inch into the copper anvil.

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Later, the relieved designer found the antenna unharmed and fully operational. Only minor modifications may be needed in the final model. This was the third test of the antenna and one more may be required before a flight model is approved.

High-impact research has led to the use of special materials, including several new plastics. It also has developed special mounting techniques for electronic, electro-mechanical and mechanical components. For example, engineers have developed tiny ball-bearings which operate well at the extreme limits of 10,000 G's and 500 feet per second.

Comuntzis defines the basic goal of his designers. "It is to take shock-resistant components and keep making them more rugged as we try to shrink them," he says.

Rough-landing spacecraft and equipment are relatively simple to design. But the engineers regard "ruggedized" equipment as essential on so-called soft landers, too. Such equipment could survive a bad landing, they say, and still return to Earth data on what happened.

A high-impact diagnostic package was designed for the Surveyor series, containing components tested to withstand 3,000 G's or more. Early lunar Rangers had scientific instruments encased in a gisnt balsa "ping pong" ball capable of withstanding 2,500 G-shock. However, this development of JPL and Philco Aeronutronic was never checked out on the moon because of mission failures.

Potentially valuable civilian applications could arise from high-impact technology, the JPL engineers say. One future development may be better crash recorders for aircraft and automobiles. Air-droppable rescue and fire-fighting equipment also could be strengthened to reduce the amount of parachuting and cushioning.

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Other possible uses: sturdier oil-field and oil-well instruments, television and other cameras, tape recorders in general, transistor radioes, and even toys.

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SPACE-TYPE SOCK: Stan Taylor, high-impact test engineer at Caltech's Jet Propulsion Laboratory, and Warren Torris (cq), technician, inspect the shattering effect of a space-simulating firing of a 22-inch test gun. The 260-pound aluminum projectile, called a sabot, was ripped apart in the test, which equalled a force of 7,400 G's. The redwood backstop was impacted to an average depth of two inches. The tests are a regular part of the JPL high-impact program to help the National Aeronautics and Space Administration develop more rugged spacecraft and shock-resistant equipment for lunar and planetary exploration.

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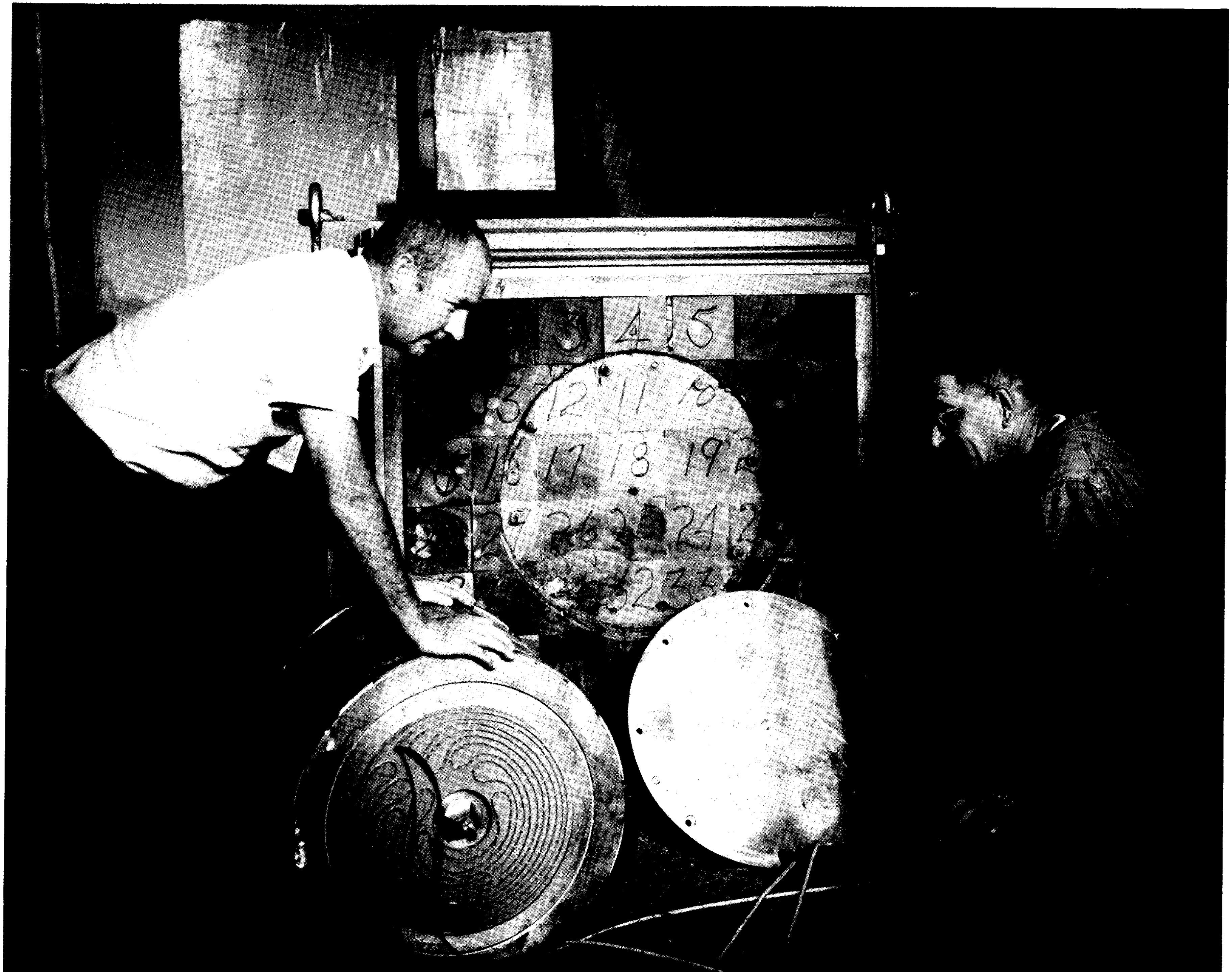
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FOR RELEASE: Sunday, October 15, 1967

JPL DOUBLE VACUUM CHAMBER FREEZES MOLECULES IN SPACE SIMULATION TESTS

PASADENA, Calif.,--A double vacuum chamber which simulates the extreme effects of interplanetary space on spacecraft has been developed by researchers at Caltech's Jet Propulsion Laboratory.

Called a Molsink chamber--Molsink is short for the molecular sink of outer space--this man-made simulator will strive to determine exactly what happens to paint, components and even micro-organisms that might be hitch-hiking on a spacecraft.

The new vacuum-within-a-vacuum captures the tiniest gas molecules by freezing them on the walls of the inner chamber at temperatures of 400 degrees below zero, Fahrenheit.

Designed by James B. Stephens of the JPL Space Simulators and Facility Engineering Section, the chamber is rated capable of capturing 99.97 per cent of all condensable molecules emanating from an item under test. It will be used soon to test a number of planetary spacecraft components for future National Aeronautics and Space Administration projects.

Conventional vacuum chambers have not been able to pump or capture more than a fraction, rarely more than half, of the gas molecules flying off a test article.

The guiding idea behind the double vacuum facility is that "the permissive environment of space," to use Stephens' phrase, can be re-created under stringent laboratory controls.

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During a spacecraft's flight, the active elements in space--particle and radiation bombardment and friction--dislodge minute bits of even the hardest-finished surfaces and can cause breakdowns of equipment. This loss is gradual, but measurable, in the form of tiny molecules of gas. These fly off randomly into the great sink of space.

Space scientists believe the Molsink chamber gives them a reliable tool to measure and counteract the problem of spacecraft out-gassing.

How did the JPL engineer build a better moltrap?

The inner test chamber--the Molsink shroud--is an eight-foot-in-diameter sphere formed by wedge-shaped aluminum fins and cooled by super-frigid helium gas.

The fluted aluminum shroud resembles a huge, shiny Japanese lantern. Fifty pairs of the metal fins, only 16-thousandths of an inch thick, are welded to aluminum cooling tubes shaped like giant hairpins.

The sharply-angled fins afford greater surface area (2,000 square feet) for capturing molecules than either radial fins or smooth walls, Stephens says. Wedge fins also decrease the number of particles rebounding toward the test item in the center of the chamber.

To improve the sticking quality of the surface, the interior is coated with a chemically active titanium vapor. This is done by sublimation. At the bottom of the shroud an electron gun focuses its beam on a titanium rod. The resulting evaporation uniformly lines the moltrap.

This chemical pumping is so effective that Stephens says up to 7 million liters of hydrogen per second, coming off a test item, could be chem-sorbed. Thus a small rocket engine may be fired in the Molsink and have all blast-out molecules captured on the walls, without damage to the facility.

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The test chamber is refrigerated by pumping the helium through the hair-pin tubes. A temperature of 21 degrees on the scientific Kelvin scale (-400 degrees, F.) is needed to obtain the highest sticking rate of common gas molecules thrown off by test articles.

This is nearing the absolute zero of -459 Fahrenheit. The moltrap requires 1,000 watts of refrigeration at 21 degrees K for continuous periods of several months.

Long test periods will simulate the actual flight time of spacecraft to planets--four months to Venus, seven months to Mars, for example.

To measure the molecular flow, super-sensitive quartz crystal micro-balances were developed for the chamber. The frequency of these quartz crystals is precisely known. As particles are deposited on their surface, the frequency changes and the particles can be measured. These devices also are used to control the rate of titanium evaporation.

The quartz crystal instruments are capable of measuring differences as fine as one-one-hundredth (1/100) of a single layer of water molecules.

A double quartz-plate window enables technicians to observe what's happening in the test chamber. The outer quartz plate is one inch thick, the inner plate is about half that and separates the test vacuum chamber from the guard vacuum surrounding it.

The outer chamber is 10 feet in diameter and 12 feet high. It is supported by two columns so that its bottom opening is 9 feet above the floor. Made of carbon steel with a stainless steel liner, it is designed so that all welds and joints exposed to the test volume vacuum are guarded by the outer vacuum.

All connections in fluid or gas lines are made within the guard vacuum space. Thus the effect of a possible leak in the Molsink test chamber is greatly reduced.

The outer chamber is cooled by liquid nitrogen to a slightly warmer temperature of about -320 degrees, F.

The large Molsink is the result of four years of experimentation with smaller models. Currently under test in a small prototype vacuum chamber are spores--tiny single-cell organisms--which could find their way onto spacecraft components. Tentative results indicate spores--regarded as the most likely form of life to try hitch-hiking in space--die off in a simulated space vacuum.

Other factors which scientists wish to check out in JPL's cold or hot vacuums include the internal heat and bearing friction generated by a spacecraft in flight.

The double-vacuum chamber is expected to be fully operational early in 1968, when test demands will be stepped up for the Mariner '69 (for Mars) program.

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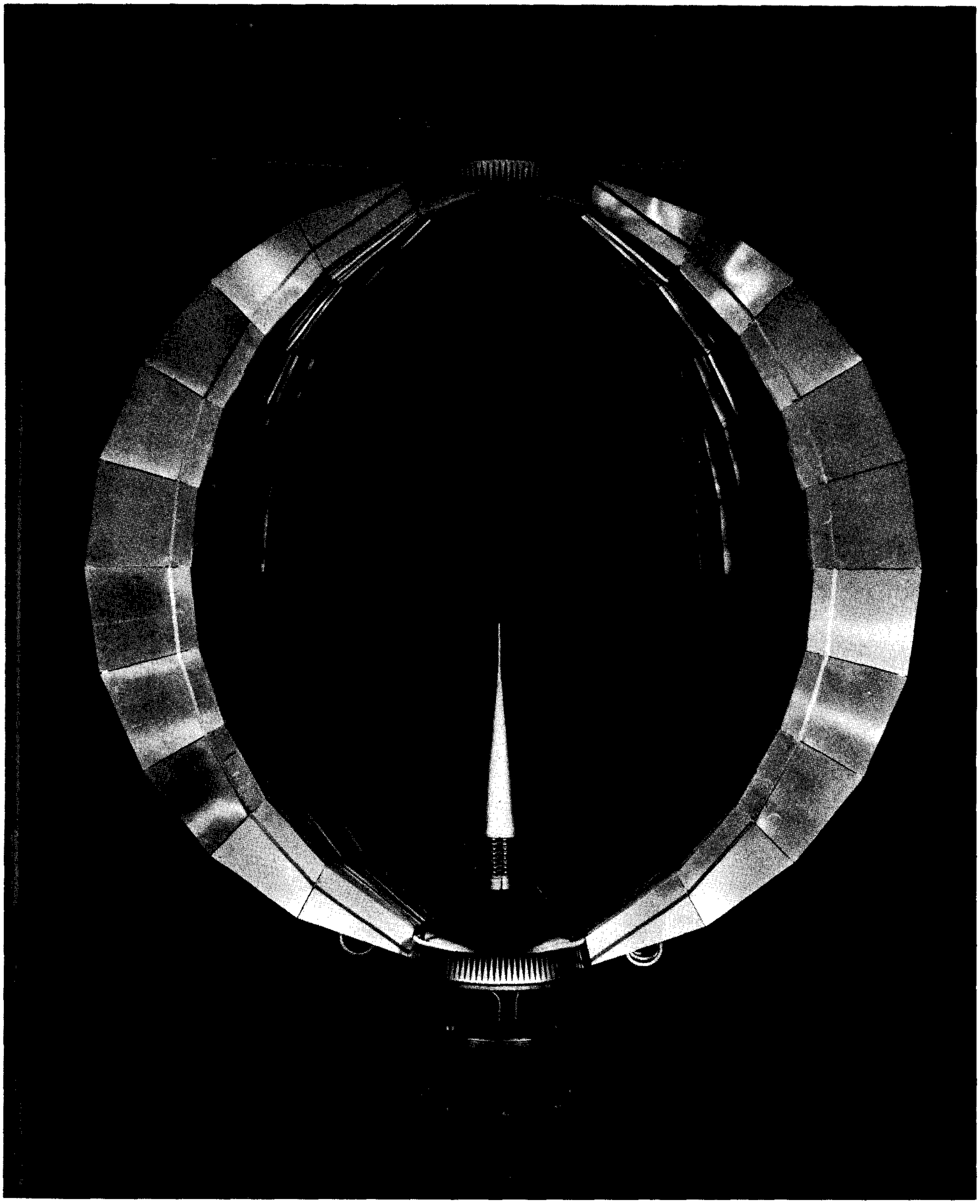
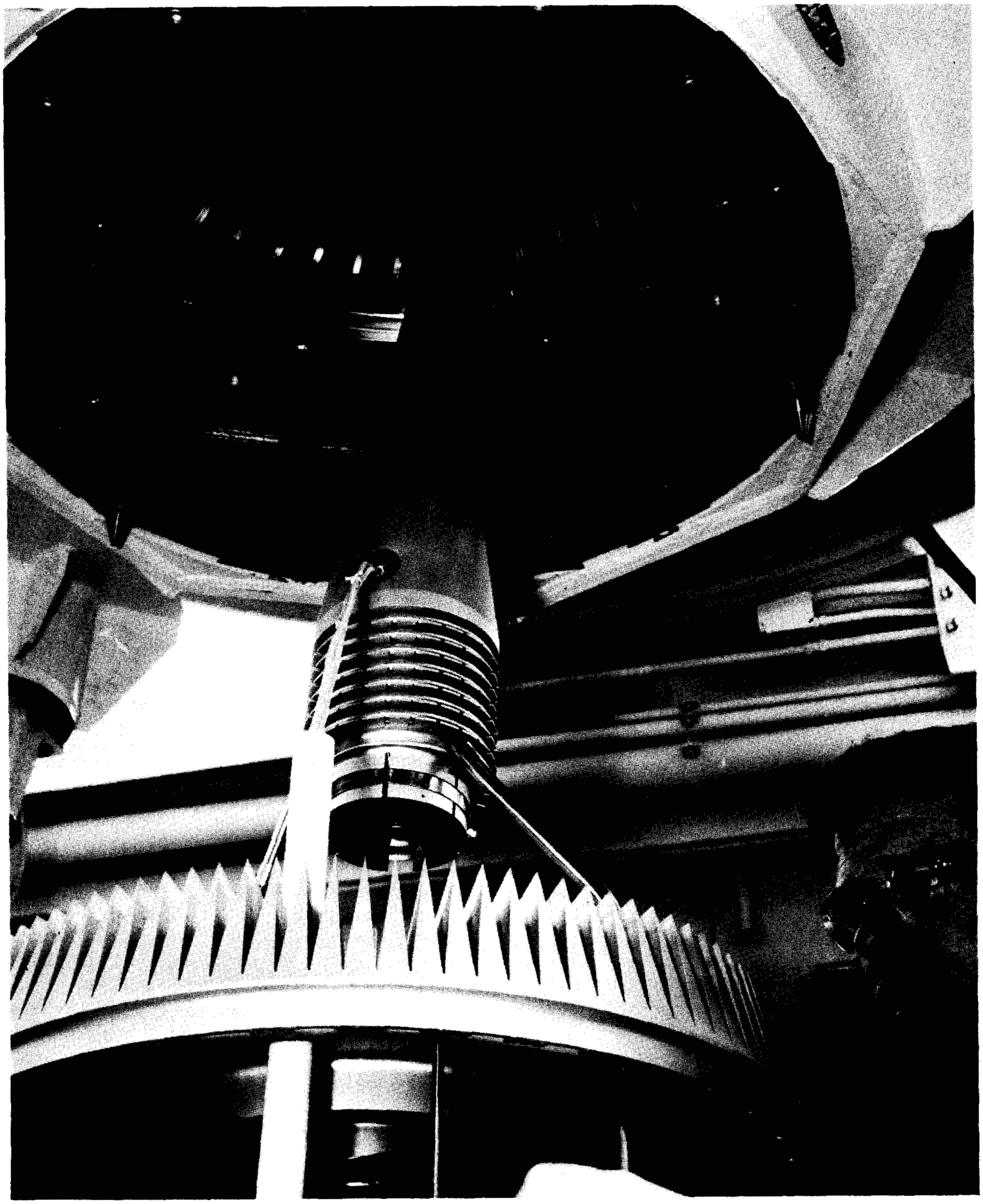


375-876 A

SUPER-COOL VACUUM CHAMBER: This aluminum wedge-fin sphere, resembling a highly-polished Japanese lantern, is the latest contribution to space vacuum technology at Caltech's Jet Propulsion Laboratory. This is the inner core of a double-vacuum chamber that, with the aid of a titanium electron gun (at bottom), freezes molecules on the chamber walls in space simulation tests. Temperatures as low as 400 degrees below zero, Fahrenheit, are obtained in the Molsink chamber, so called becuase it reproduces the molecular sink phenomenon of outer space. The chamber was built at JPL for testing what can happen to a spacecraft in flight on planetary missions of the National Aeronautics and Space Administration.



375-967 B

SUPER-COOLING GUN: James Stephens, engineer, makes final adjustments on the titanium electron gun which cools the double-vacuum space simulation chamber he designed for Caltech's Jet Propulsion Laboratory. The titanium sublimation process reduces temperatures to 400 degrees below zero, Fahrenheit, in the chamber. The chamber is called a Molsink, because it recreates the molecular sink of outer space. On these super-cold walls, testers such as Stephens are able to trap gas molecules which escape from spacecraft parts under vacuum conditions. The chamber was built at JPL to test what can happen to a spacecraft in flight on planetary missions of the National Aeronautics and Space Administration.

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NOTE TO EDITORS:

The Mariner V spacecraft will fly-by the planet Venus Thursday morning, October 19. The encounter sequence will begin at 9:30 a.m., PDT, with the point of closest approach occurring at 10:34 a.m., PDT. The encounter sequence will end at 11:49 a.m. when the spacecraft's tape recorder is turned off.

Read-out of the tape recorder and transmission of science data back to earth will require another 48 hours. This covers a waiting period of 14 hours before the playback begins and 34 hours for the taped data to be transmitted.

A pre-encounter briefing by Mariner/Venus project officials will be held at 2:00 p.m., PDT, Wednesday, October 18, at the Von Karman Auditorium at JPL, 4800 Oak Grove Drive, Pasadena, California.

Press conferences to follow encounter will cover engineering aspects of the fly-by and scientific data that was reported in real-time from the spacecraft and not stored on tape. These conferences will be held at JPL and will be announced in advance to allow planning for coverage.

The press room will be open in the Von Karman Auditorium at 8:00 a.m., PDT, Wednesday, October 18.

The following public information people will be available:

	Home Phone	Press Room Phone	Office Phone
Frank Colella	790-1652	354-6400	354-5011
Frank Bristow	790-5140	354-6400	354-5011
Bob Mac Millin	790-7849	354-6400	354-5011
Alan Wood	355-1814	354-6400	354-5011

Frank J. Colella

Frank J. Colella

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FOR RELEASE: A.M.'s of Sunday, October 29, 1967

PASADENA, Calif.-- Dr. William H. Pickering, Director of Caltech's Jet Propulsion Laboratory, today announced the appointment of Fred H. Felberg to the new position of Assistant Laboratory Director for Plans and Programs.

Jack N. James, Deputy Assistant Director of JPL for Flight Projects, has been named to Felberg's former position as Assistant Laboratory Director for Technical Divisions.

Dr. Pickering said Felberg will be responsible for planning JPL's total program, including, in addition to the technical program, the effective distribution of manpower and resources.

James, he said, will be responsible for the efficient utilization of the Laboratory's technical resources in meeting its responsibility for the unmanned exploration of the moon and planets for the National Aeronautics and Space Administration.

Felberg, a native of Los Angeles, received a B. S. degree in mechanical engineering in 1942 and an M. S. in aeronautics in 1945, both from Caltech. He joined JPL in 1960, served as manager of the Engineering Mechanics Division and was appointed Assistant Laboratory Director for Technical Divisions in 1964. Earlier, he was Associate Director of the Southern California Cooperative Wind Tunnel at Caltech and a lecturer in aeronautics at the Institute.

James, born in Dallas, Texas, was graduated from Southern Methodist University in 1942 with a B. S. in electrical engineering and received his M.S.E.E. from Union College in 1948. He served with the U. S. Navy during

-more-

World War II and worked with General Electric and RCA from 1945 to 1950 when he joined JPL. Prior to his appointment in 1965 as Deputy Assistant Laboratory Director for Flight Projects, James was manager of the Mariner Venus and Mariner Mars projects which resulted in the first successful exploration of the two planets in 1962 and 1965, respectively.

Felberg resides in Altadena, California, with his wife, Jean, and their three children. James, his wife, Ruth, and their four children live in La Canada, California.

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460--10/24/67

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FOR RELEASE: Sunday, December 10, 1967

JPL MINI-RECORDING RESEARCH PRODUCES PIN-POINT DATA STORAGE TECHNIQUE USING LASER AND SPECIAL MAGNETIC FILM

PASADENA, Calif.--Someday spacecraft to the Moon or Mars may store data for 500 photographs on a one-inch square strip of magnetic film. And computers aboard these spacecraft may retain ten million bits of scientific information per square inch of film.

These probabilities loom bright with a development in microscopic or mini-recording achieved by two researchers at Caltech's Jet Propulsion Laboratory. Dr. Dimiter I. Tchernev and Dr. George W. Lewicki have succeeded in recording magnetic spots or "bits" with diameters smaller than one micron, or forty millionths of an inch, on thin films of manganese bismuthide.

The recording method, which employs the pulsed light beam of a laser, has proven the film can retain several hundred times more data than is generally stored on present magnetic film or tape.

The JPL project for the National Aeronautics and Space Administration has yielded, in the words of the researchers, "what we believe to be the smallest magnetic bits of information ever recorded." They report on their work in a journal of the Institute of Electrical and Electronics Engineers.

Success of the laser-magnetic film process may lead to a substantial reduction in the size of computers needed on long-range planetary missions. Used in conjunction with television cameras, Tchernev says, it would store one thousand times as many pictures as the present video tape method used for lunar and planetary photography.

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The writing is done with a pulsed ruby laser similar to the type used by eye surgeons to "spot-weld" detached retinas. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

The laser beam is focused on the film through a microscope and reduced to micron size. A micron (one-thousandth of a millimeter or 40-millionths of an inch) is barely a pinpoint to the human eye. Laser intensity was regulated to heat spots to 360 degrees, Centigrade, (680 degrees, Fahrenheit) and no more. By reducing the beam strength slightly, the researchers recorded spots only a half-micron wide.

Mini-recording technique relies on what electrical engineers call Curie-point writing. This involves momentarily heating a section of magnetized manganese bismuthide. Curie-point is named for Pierre Curie, French scientist who discovered that magnetization vanishes at high temperatures.

As a heated spot cools, the direction of its magnetization is reversed by cooler portions of film around it. At that moment, a bit of data can be magneto-printed, so to speak, on the film.

Extra-thin film is used for the recording. It is only 700 angstroms thick--7/100,000 of a millimeter, or 3/100,000 of an inch. The film is produced under vacuum, with manganese and bismuth being evaporated in that order into a mica base. The process turns out one film strip every four days, but is being stepped up to produce 12 samples in that period.

The recorder bits of information are viewed with the aid of two polarizing crystals, polaroid light and a microscope with an enlargement power of 500. Depending on the setting of the crystals, the bits are seen either as black spots on a white background, or white on black.

Portions of the film show light or dark depending on their magnetization.

(more)

This is in accordance with the magnetic rotating principle called the Faraday effect, named for its discoverer, Michael Faraday.

Magnetic film has an important advantage over photographic film, according to the researchers. Information recorded on magnetic film can be erased at will and written over, if necessary. Bits can be wiped out and new data printed in their places by alternate heating and cooling.

With further development, the laser-magnetic film technique could significantly reduce the size of many computers. The JPL scientists say one square inch of magnetic film could hold all information contained in computer memories now bulking ten cubic feet. A memory, in computer parlance, is the retentive component that stores data the computer needs to solve a problem.

Additional experiments are under way at JPL to develop a further understanding of the Curie-point technique for spacecraft applications. Magnetic information storage is one of NASA's strong continuing interests. Present funding for the Jet Propulsion Laboratory contract is $175,000 a year.

Dr. Tchernev is currently on one-year leave from JPL, teaching in the University of Texas electrical engineering department. Dr. Lewicki will head the experimental staff in his absence. The work is being done for the JPL Guidance and Control Division.

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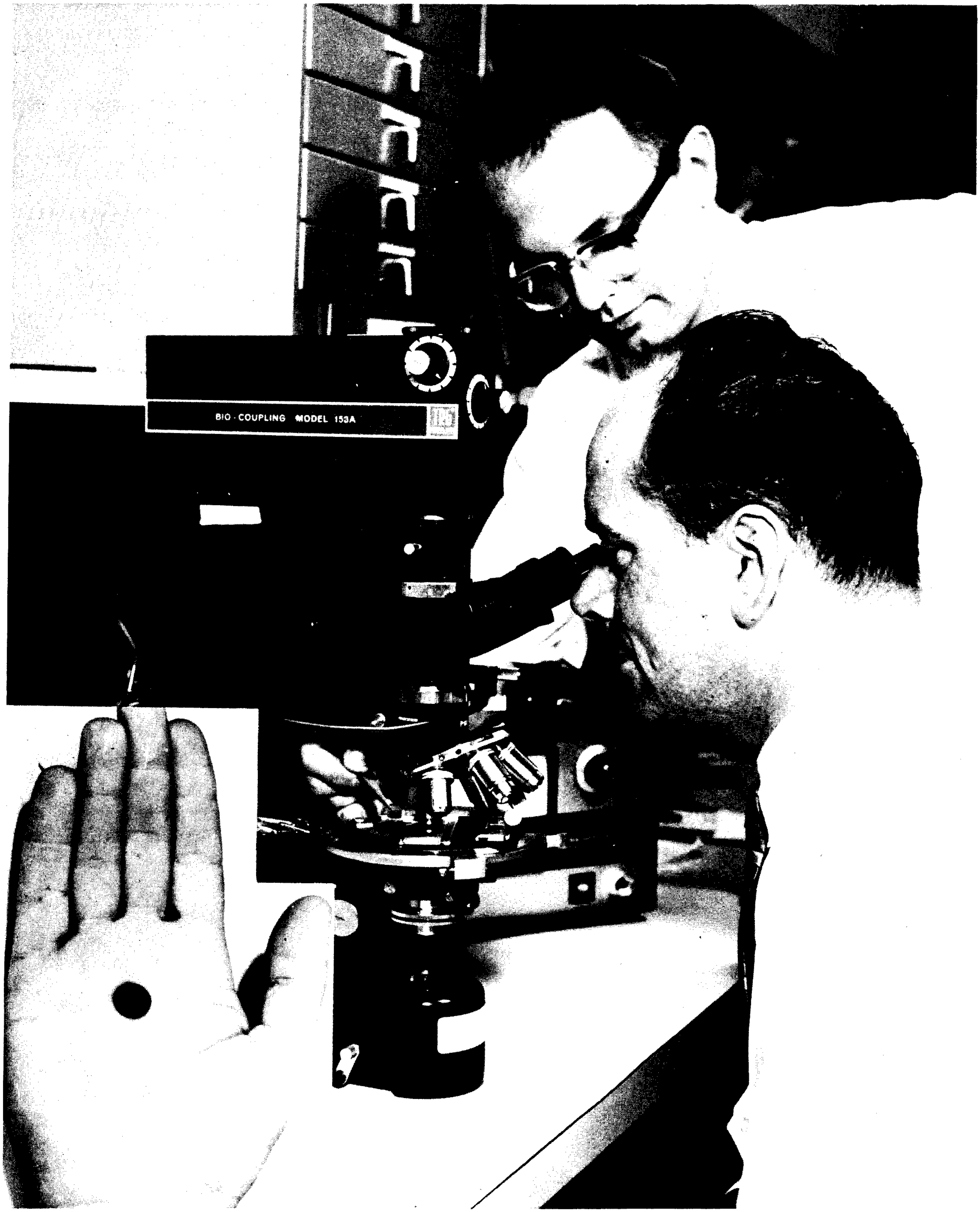
MINI-RECORDING: Dr. Dimiter I. Tchernev looks through microscope of laser instrument as Dr. George W. Lewicki inserts magnetic film for test of the miniature recording technique which they have developed at Caltech's Jet Propulsion Laboratory. Drs. Tchernev and Lewicki use a ruby laser light beam and special magnetic film to record several hundred times more data than can presently be stored on comparable size tape or film. Insert at lower left shows film disc, less than an inch in diameter, on which several million bits of scientific information can be imprinted by the laser beam. The process could lead to substantial reduction in size of computers needed aboard planetary spacecraft and vastly increase the amount of data and number of pictures that can be stored in those computers. The JPL research development was conducted for the National Aeronautics and Space Administration.


BIO-COUPLING MODEL 153A

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FOR IMMEDIATE RELEASE January 24, 1968

PASADENA, California--Rear Admiral John E. Clark, USN (Ret.), has been named deputy director of the Jet Propulsion Laboratory of the California Institute of Technology, it was announced today by Dr. William H. Pickering, JPL director. Adm. Clark will assume his new duties on February 19.

Concluding a distinguished naval career, Adm. Clark retired last September. He was commandant of the Twelfth Naval District, with headquarters in San Francisco, since September, 1965.

Adm. Clark's experience in research and development began in 1935 when he was assigned to the Experimental Aircraft Division of the Norfolk, Virginia, Naval Air Station. From 1947 to 1949, he was chief of the Air Objectives Section in the Office of the Assistant Chief of Naval Operations. He was the Navy member on the staff of the Director of Guided Missiles in the Office of the Secretary of Defense during 1952 and 1953.

In 1954, he became commander of the Naval Air Missile Test Center at Point Mugu, California, and the following year was named Director of Guided Missiles in the Office of the Chief of Naval Operations.

Adm. Clark was appointed deputy director of the Advanced Research Projects Agency, Department of Defense, in 1958. He returned in 1961 to Point Mugu, serving as commander of the Pacific Missile Range until September, 1965.

A native of Atchison, Kansas, Adm. Clark was graduated from the U. S. Naval Academy and commissioned Ensign in 1927. Detached from sea duty in 1931, he received flight training at the Naval Air Station, Pensacola, Florida, and was redesignated Naval Aviator.

Following World War II, Adm. Clark's assignments included commanding officer of the aircraft carrier, USS Wright. He commanded Carrier Division Sixteen from 1959 to 1961.

Adm. Clark is married to the former Amelie Largue of Pensacola. They have a son, Jack Largue Clark. Adm. and Mrs. Clark currently are moving their home from San Francisco to the Pasadena area.

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FOR RELEASE: Sunday, April 21, 1968

PASADENA, California--Despite the blazing California sun, there is a small corner of Caltech's Jet Propulsion Laboratory that is forever Antarctica.

In a small walk-in freezer laboratory, simulated Antarctic cold--down to 22 degrees below zero, Fahrenheit--keeps Antarctic soil acclimated. Here more than a ton of dirt is kept in hibernation by Dr. Roy E. Cameron and his JPL Soil Sciences Group.

This week Dr. Cameron and his colleagues received another half-ton of soil from 'way down under, collected during the 1967-68 Antarctic summer. This, along with many samples they dug in 1966-67, will be tested and cultured to see what types of microorganisms live in extreme cold.

The JPL team is seeking clues to help man determine someday what, if anything, grows on Mars. The studies are sponsored by the National Aeronautics and Space Administration and the National Science Foundation.

Thus far, experiments show that Antarctic soil kept laboratory-frozen more than a year can be made to grow bacteria, yeasts, molds and algae within two weeks when subjected to room temperature--68 degrees or above. They also grow more slowly at temperatures just above freezing.

The JPL soil samples came from high, dry valleys in Victorialand near the United States base at McMurdo. Some were taken from the surface, others, six to 12 inches deep.

This year, Dr. Cameron and two assistants used a jackhammer to dig samples from the permafrost as deep as two feet, where they found an abundance of micro-organisms.

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"If there is permafrost on Mars," the JPL scientist says, "the chances of life will be increased."

In some Antarctic soils, the number of microorganisms almost doubles in the permafrost. The frozen layer preserves soil bacteria, some quite ancient. If the subsurface soil occasionally thaws, the released water aids their growth.

Dr. Cameron's Antarctic assistants this year were Dr. Jonathan King and Charles David of the Caltech biology department. They spent two months digging and conduting soil and microbiology tests in the McMurdo Sound area during the Antarctic summer season, returning home recently.

In 1966-67, Dr. Cameron was assisted by Howard Conrow, technician in the JPL Soil Science Laboratory.

Cameron and Conrow built the walk-in freezer lab addition from a converted Navy refrigeration unit. The super-cooled (six fans) 12 x 20-foot box keeps samples at their native temperatures until the scientists are ready to put them to the growing test. Minimum temperature inside varies from -15 to -22 degrees (F) depending on the sun's heat on the flat roof. Walls and ceiling are about six inches thick.

The soil scientists don parkas and full Antarctic gear whenever they go into the box to work. Samples are weighed, sifted and cataloged there. Dirt is carefully kept in labeled bags, bottles and vials until ready for testing. Hundreds of samples are under culture, thousands more will be within months.

The work probably will be continuing right up to the time the United States lands a soil sampler and begins digging on supposedly frigid Mars sometime in the 1970's. Scientists hope to make Mars soil diggers and analyzers even more sophisticated than those aboard several Moon Surveyors.

-more-

About 100 pounds of Antarctic soil also was shipped to NASA's Lunar Receiving Laboratory at Houston for comparison with the first Moon samples to be brought back by Apollo astronauts.

What results have been obtained from the Antarctic soil thus far?

Seven types of microorganisms live, if not flourish, in the so-called dry valleys. Three are in the bacterial group, four are in the algae family. These are among the smallest microflora (sub plant life) yet discovered on Earth--being only a micron--1/25,000th of an inch--in diameter.

As many, if not more, microorganisms were found below the surface, especially at the level of hard, icy permafrost, as at the surface. Subsurface bacteria are generally nonpigmented. Colored bacteria were usually found at the surface. Pigment protects them from adverse radiations.

The ice-desert of Antarctica has less life than any desert soil yet investigated on Earth.

Cameron and Dr. Norman H. Horowitz, JPL bioscience section manager who suggested the Antarctic studies, believe they will help scientists to decide what type of life-detection equipment should be sent on a Mars lander. Dr. Horowitz says the studies also will provide relevant information on spacecraft quarantine and sterilization problems.

On the Mariner 1969 Mars twin spacecraft, only fly-by experiments will be performed. However, NASA and JPL scientists hope a Mars landing will be achieved by the U. S. in the next decade.

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FOR RELEASE: AM's OF TUESDAY, APRIL 23, 1968

A model of a wheel-shaped planetary landing craft, sterilized by heat and dropped from an altitude of 250 feet, has operated successfully after impacting the ground at 80 miles per hour.

The test, conducted recently by the Jet Propulsion Laboratory for NASA, was a major step in a research and development program to demonstrate the feasibility of sending a lightweight scientific landing capsule to Mars in the near future.

For a simulated Martian surface, JPL engineers selected the "hardpan" bed of a dry lake near the Goldstone Space Communications Complex in California's Mojave Desert.

The $63\frac{1}{2}$-pound lander was released from a hovering helicopter and allowed to free-fall to the lake bed. In the thin atmosphere of Mars, the lander would be slowed to the same velocity by a 20-foot parachute. No parachute was used in the test.

Thirty seconds after the lander struck the surface, its radio transmitter turned on and operated for a scheduled 20 minutes. At impact plus three minutes, a tiny anemometer--wind velocity detector--deployed automatically from the lander at the end of a four-foot telescoping metal instrument boom.

A wind measurement is one of the prime experiments under consideration for initial planetary landing missions. Others include investigation of surface pressure, temperature, water vapor and low-mass atmospheric constituents.

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Following a mission profile identical to projected Mars surface operations, the lander's radio turned on again 22 hours after the initial transmission (when the Earth would again be in view). Signals from the three-watt transmitter were received for another 40 minutes to conclude the test.

The lander made a stable fall striking the lake bed on its flat bottom side. It bounced several inches and left a two-inch depression in the ground.

Resembling an automobile tire and wheel, the 22-inch diameter lander was protected on all surfaces by balsa wood, which absorbed the greater portion of the landing shock. Examination of the balsa after the test showed a predicted amount of crushing.

The anemometer, which spun freely in the desert gusts at Goldstone, consisted of three cone-shaped collapsible metal cups. The instrument boom supporting the anemometer sprang from its stowage compartment near the hub of the "wheel."

The lander was powered by a 12-cell silver-zinc battery, the first known to survive both heat sterilization and high-velocity impact.

Because of planetary quarantine requirements, the entire lander system was sterilized by heating it for 24 hours at a temperature of 257° F.

On a Mars mission the lander, combined with an atmospheric entry probe, would separate from an interplanetary spacecraft in the vicinity of the planet. Aerodynamic braking and protection against frictional heating would be provided be a sphere-cone aeroshell.

As velocity slows to near-sonic speeds, the lander would separate from the capsule and parachute to the surface. The lander transmits directly to Earth for a 20-minute period. Its three-watt radio signal can be received across the Mars-Earth distance by a super-sensitive receiver coupled to the 210-foot antenna at Goldstone.

The landing craft's data handling system stores science and engineering measurements during the following 22 hours for transmission to Earth when the communications link is re-established for a 40-minute period. All lander events occur automatically by initiation from an internal sequencing and timing system.

The Goldstone test was based on several years of research at JPL in the areas of high-impact design techniques, heat sterilization of sensitive electronic equipment, packaging and minaturization.

The project was managed by John H. Gerpheide in JPL's Project Engineering Division. Capsule system engineer was Kane Casani and the test conductor was Wally Castellana. Hardware was developed by the Laboratory's technical divisions.

JPL is operated for NASA by the California Institute of Technology in Pasadena, California.

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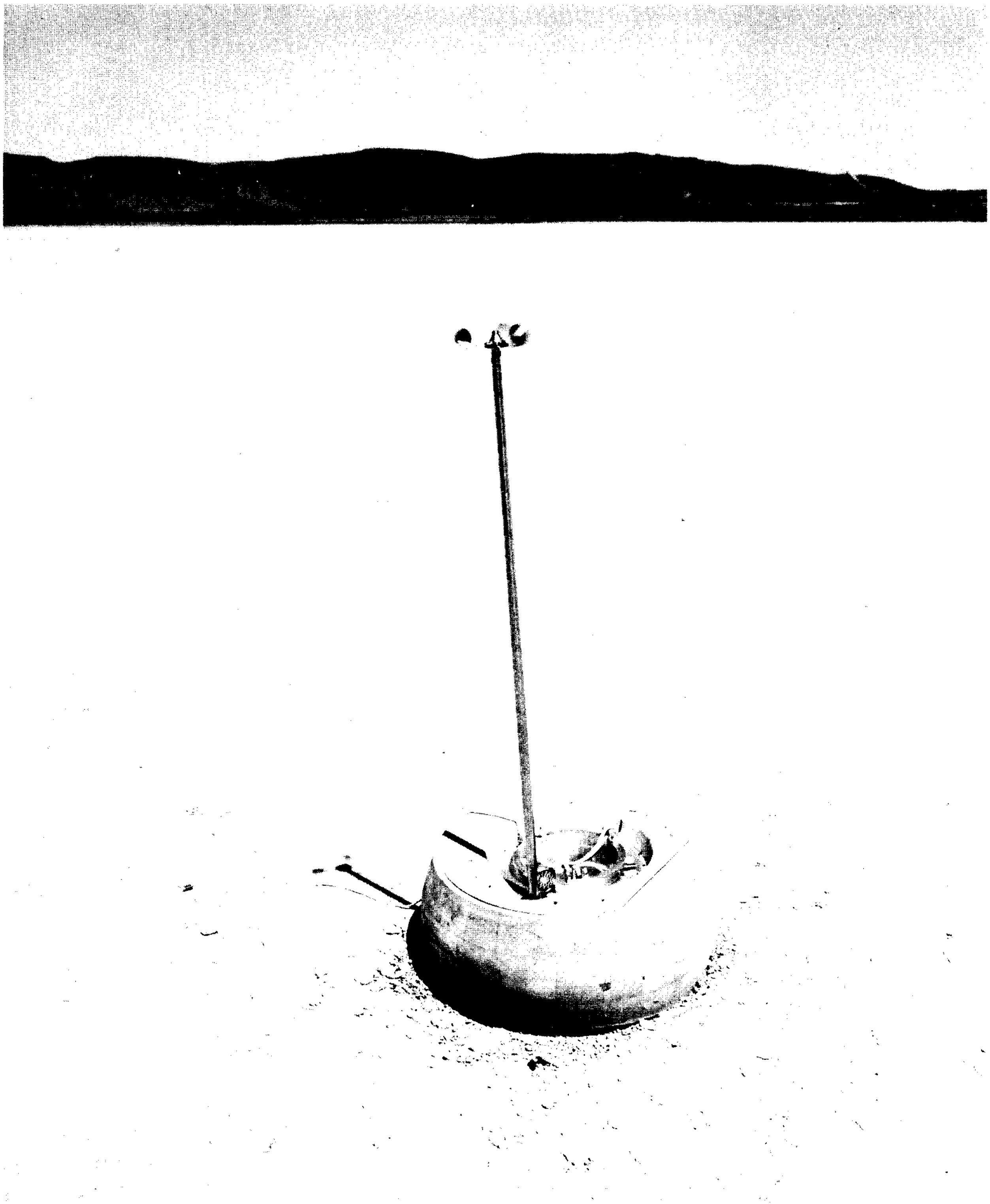
473-4/16/68

Jet Propulsion Laboratory engineers examine wheel-shaped planetary landing craft after it had survived heat sterilization and high-velocity impact on Goldstone Dry Lake in California's Mojave Desert. The 63 1/2-pound lander, cushioned by balsa wood, was dropped 250 feet from a hovering helicopter and struck the ground at an 80-mile-per-hour velocity, leaving a two-inch depression in the lake bed. Lander automatically deployed anemometer (spinning cups atop instrument boom) and switched on its radio transmitter after impact. Test, conducted by JPL for NASA, demonstrated feasibility of sending instrumented landing craft to Mars. Engineers are (from left) Kane Casani, John H. Gerpheide and Wally Castellana.



Wheel-shaped planetary landing craft operates successfully on dry lake bed where it impacted the ground at 80 miles per hour in a test to demonstrate feasibility of sending instrumented payloads to land on Mars. Lander was sterilized by intense heat to satisfy planetary quarantine requirements and dropped 250 feet from a helicopter onto Goldstone Lake in California's Mojave Desert. Balsa wood covering absorbed most of landing shock. Spinning cups atop telescoping boom comprise anemometer--wind velocity detector--one of a number of instruments under consideration for initial planetary surface experiments. Test was conducted for NASA by the California Institute of Technology Jet Propulsion Laboratory, Pasadena, California.

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Pasadena, California
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FOR RELEASE SUNDAY, MAY 12 1968

Pasadena, Calif. -- Letters from American Presidents, scribbled laboratory notes and diaries and other personal papers of famous scientists are now being collected, catalogued and filed as part of an archives program at the California Institute of Technology.

"Our goal is to preserve these important papers for scholars and future generations," said Dr. Daniel J. Kevles, assistant professor of history. "Man makes science, and these papers record the excitement, the groping, the controversies and the politics of a fascinating human enterprise."

Kevles, who started work on the documents two years ago, said papers belonging to the late Dr. Robert A. Millikan, the Nobel laureate who served as administrative head of Caltech for 24 years, and the late Dr. George Ellery Hale, founder of the

(more)

Mt. Wilson and Palomar Observatories and one of the creators of modern Caltech, have been catalogued and are now available for use by qualified scholars.

Kevles added that work is now under way on the papers of the late Dr. Theodore von Karman, the famed Caltech professor of aeronautics who helped found Caltech's Jet Propulsion Laboratory. The task is under the direction of Mrs. Judy Goodstein, a Ph.D. in the history of science, who supervises the archival work.

The Hale papers have been published in microfilm under a grant from the National Historical Publications Commission.

"We filmed about 109,000 pages," Dr. Kevles said. "The things we didn't film -- such as meeting minutes and some business records -- are either available elsewhere or weren't considered too important."

Kevles said the Hale papers are owned by the Carnegie Institution of Washington and are in Caltech's care until a new headquarters for the observatories is built on the Caltech campus. The observatories are operated jointly by Carnegie and Caltech.

"Many of these documents, especially the Hale papers, are informative about the kind of political troubles that have beset

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science in the twentieth century," Kevles said.

"For example, Hale, who created the National Research Council during the First World War, tried to extend it to the international level with the International Research Council, the parent of today's International Council of Scientific Unions.

"Allied scientists were determined to exclude Central Powers scientists from membership. The formation of the international council bespeaks the first catastrophic breakdown of the international scientific community after the Napoleonic era."

Kevles explained that Hale "was in the center of it all, caught in the vengefulness of the Allied scientists, his own bitterness against German scientists and the political commitments of President Woodrow Wilson."

"There are several letters in the files from President Wilson. The President made it a point to differentiate between the German people and their leaders, exempting the people from responsibility for the crimes of the Kaiser.

"But Allied scientists -- including Hale -- declined to make this differentiation," Kevles continued. "The Allies insisted they couldn't meet with their former enemies until the German scientists renounced the 'barbarous' practices of their country.

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"Hale was seeking President Wilson's support for the International Research Council, but the president refused to commit himself for fear it would jeopardize his own efforts for peace and the League of Nations."

There are also letters in the files from Albert Einstein, who was on the Caltech faculty in the early 1930s. Einstein, said Kevles, "was one of the few German scientists who opposed the war. But when he visited the United States in 1921, many American scientists considered him an agent of German propaganda and insisted he be given no official recognition by such agencies as the National Academy."

The Millikan papers, which include eight boxes of photographs, letters from famous statesmen and scientists, plus personal items, are now in the new Millikan Library. With the addition of the von Karman papers, the archives facilities are pressed for space. Kevles said it is expected that the expanding archives will be placed permanently in a large room in what is now the Gates Laboratory of Chemistry.

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FOR IMMEDIATE RELEASE: TUESDAY, MAY 28, 1968

A heat-sterilized planetary landing craft will be dropped from an altitude of 250 feet onto an asphalt surface in a Jet Propulsion Laboratory test on Tuesday, May 28.

The test will be a major step in a research and development program for the National Aeronautics and Space Administration to demonstrate the feasibility of sending a lightweight scientific landing capsule to Mars in the near future.

For a simulated Martian surface, JPL engineers selected an asphalt roadway near the Goldstone Space Communications Complex in California's Majave Desert. In a test conducted last April 4, the lander operated successfully after a drop from the same altitude onto the bed of a dry lake at Goldstone.

The 63½-pound lander will be released from a hovering helicopter and allowed to freefall at 80 miles per hour to the roadway. On a mission to Mars, where the atmosphere is about 200 times thinner than Earth's, the lander would be slowed to the same velocity by a 20-foot parachute. No parachute will be used in the test.

Thirty seconds after the lander strikes the road, its radio transmitter will turn on and operate for a scheduled 20 minutes. At impact plus three minutes, a tiny anemometer--wind velocity detector--will deploy automatically at the end of a four-foot telescoping metal instrument boom.

A wind measurement is one of the prime experiments under consideration for initial planetary landing missions. Others include investigation for surface pressure, temperature, water vapor and low-mass atmospheric constituents.

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Part of the simulated Mars mission will be speeded up for this test. The three-watt radio will turn itself off at 20 minutes after touchdown and on again about 20 minutes later for a second brief transmitting period to conclude the test. During an actual mission, the radio-off time would be about 22 hours, after which the Earth would again be in view of the lander's antenna.

Resembling an automobile tire and wheel, the 22-inch-diameter lander is protected on all surfaces by balsa wood, which absorbs the greater protion of landing shock.

The anemometer consists of three cone-shaped collapsible metal cups. The instrument boom supporting the anemometer springs from its stowage compartment near the hub of the "wheel."

The lander is powered by a 12-cell silver-zinc battery, the first known to survive both heat sterilization and high-velocity impact.

Because of NASA's planetary quarantine requirements, which must be met on an actual mission, the entire lander system has been sterilized by heating it for 24 hours at a temperature of 257°F.

On a planetary mission, the lander would be carried to Mars on a Mariner-class spacecraft probably launched by an Atlas-Centaur rocket combination. The lander combined with an atmospheric entry probe would separate from the Mariner in the vicinity of the planet. Aerodynamic braking and protecting against frictional heating is provided by a $6\frac{1}{2}$-foot sphere-cone aeroshell.

As the velocity slows to near-sonic speeds, the lander is separated from the remainder of the capsule and parachutes to the surface. The lander transmits directly to Earth for a 20-minute period. Its three-watt radio signal can be received across the Mars-Earth distance by a super-sensitive receiver coupled to the 210-foot antenna at Goldstone.

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The landing craft's data handling system stores science and engineering measurements during the following 22 hours for transmission to Earth when the communications link is re-established for a 40-minute period. All lander events occur automatically by initiation from an internal sequencing and timing system.

Major differences between this test and the drop test conducted on April 4-5 are:

1. The drop on asphalt will produce a deceleration load of about 2500 G's compared with 1250 to 1300 G's on the dry lakebed. Terminal velocity will be about the same--80 miles per hour.
2. Time cycle of the mission profile will be compressed from 22 hours to about one hour so that the entire test will be completed one hour after the drop.
3. A simulated data system, which did not fly in April, will be tested for the first time. (Performance of this system will not be assessed until the lander is returned to JPL.)
4. The entire capsule system--including the lander, atmospheric entry system and aeroshell--have been heat-sterilized for this test. (Only the lander and its bals wood impact limiter were sterilized for the previous drop.)

The Goldstone test is based on several years of research at JPL in the areas of high-impact design techniques, heat sterilization of sensitive electronic equipment, packaging and miniaturization.

The project is managed by John H. Gerpheide in JPL's Project Engineering Division. Capsule system engineer is Kane Casani and the test conductor is

-more-

Wally Castellana. Hardware was developed by the Laboratory's technical divisions.

JPL is operated for NASA by the California Institute of Technology in Pasadena, California.

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478-5/27/68

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FOR RELEASE: Thursday, July 4, 1968

PASADENA, Calif.--Dr. William H. Pickering, Director of Caltech's Jet Propulsion Laboratory, today announced the appointment of Dr. Robert V. Meghreblian to the newly-established post of Deputy Assistant Laboratory Director for Technical Divisions.

Dr. Donald P. Burcham, deputy manager of JPL's Space Sciences Division has been named to Dr. Meghreblian's former position as manager of the division.

The Technical Divisions Office, headed by Assistant Laboratory Director Jack N. James, is responsible for the utilization of JPL's technical resources in meeting its responsibility to NASA for the unmanned exploration of the moon, planets and deep space.

Dr. Meghreblian, a naturalized U. S. citizen, was born in Cairo, Egypt. He came to this country at an early age and received his preparatory education in New York State. In 1943, he was graduated from Rensselaer Polytechnic Institute with a Bachelor's degree in aeronautics engineering.

Following service with the U. S. Navy, during World War II, he resumed his studies at Caltech under a Guggenheim Fellowship, receiving his M. S. in aeronautics and mathematics in 1953.

A noted figure in nuclear reactor analysis, Dr. Meghreblian was associated with the Oak Ridge National Laboratory in Tennessee from 1952 to 1958. He joined the JPL staff in 1958 and has been a division manager in the sciences area since 1960.

Dr. Burcham, a native of Portland, Oregon, was graduated from Reed College, Portland, in 1937, with a Bachelor's degree in physics. He earned his Ph. D. in physics at the University of Washington in 1942.

Before joining JPL in 1963, Dr. Burcham was with the U. S. Navy Bureau of Ordnance, University of Washington Applied Physics Laboratory, National Bureau of Standards and Emerson Research Laboratories. He was president and board chairman of Aerolab Development Company of Pasadena, Calif., from 1961 to 1963.

Dr. Burcham managed advanced Mariner projects for JPL and the Advanced Planetary Missions Technology Office until the appointment to his former Space Sciences post at the beginning of 1968.

Dr. Meghreblian resides with his wife and their two children in Pasadena. Dr. Burcham, his wife and two children live in La Canada, Calif. The Burchams also have a married daughter and a grandchild.

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480/6/27/68

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FOR RELEASE: THURSDAY, P.M. OCTOBER 17, 1968

PASADENA, Calif.--An important advance toward eventual global weather prediction was reported this week by atmospheric scientists of Caltech's Jet Propulsion Laboratory and Ohio State University.

A recent successful high-altitude balloon experiment conducted in Texas by JPL researchers indicated that sunlight reflected from Earth would pose no obstacle to continuous effective operation of radiation sensors carried by spacecraft in Earth orbit.

The problem of reflected radiation was one of the factors which could affect the potential of these instruments, called spectrometers, for obtaining a temperature profile of the Earth's lower atmosphere.

The researchers concluded that such satellite-borne instruments could probe the atmosphere in sufficient detail to provide the basis for global weather prediction. The National Aeronautics and Space Administration backed the research. Caltech operates JPL for NASA.

In a nine-hour flight up to a height of 24 miles (126,500 feet), the helium-filled balloon carried an 800-pound instrument package on its atmospheric probe. The flight originated at the National Center for Atmospheric Research Station at Palestine, Texas, and ended 600 miles away at Marfa, Texas, near the Mexican border.

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Prof. John H. Shaw, Ohio State University physicist, was principal scientific investigator for the project. A nine-man JPL group was headed by Peter Schaper, scientific co-experimenter, and James H. Riccio, cognizant engineer.

In 1959, Dr. Lewis Kaplan of JPL first suggested the idea of a polar-orbiting satellite to provide temperature, moisture and cloud height data by recording the spectrum of upwelling infrared radiation in the atmosphere. The concept was tested in subsequent balloon and aircraft flights, but on last July 11 for the first time measurements were made with the detail required for use in long-range weather prediction.

A new highly accurate mathematical method for reducing the data, developed by Dr. Moustafa Chahine of JPL, was used to obtain the detailed results.

The high-frequency infrared radiation-measuring spectrometers obtained both night and daytime temperature readings and were parachuted to Earth.

To obtain necessary detail, the equipment employed shorter wavelengths than had been previously used. At these wavelengths, it was feared that reflected sunlight would interfere with the measurements. The successful balloon flight proved these fears to be unfounded.

Intensive analysis of the recorded data also disclosed that night and daytime soundings of clear and cloudy conditions can be obtained, and that Earth surface temperatures were read to within one degree of accuracy from the maximum float altitude of 24 miles.

At this height, at 4:36 a.m., three hours after launch, the JPL-developed multidetector spectrometer gave an Earth surface reading of 66 degrees, Fahrenheit, verified to within a degree by nearby U. S. Weather Bureau stations. Other temperatures at the time, as calculated from radiance data, ranged from 85 degrees below zero F., at 53,000 feet, up to 8 degrees above zero at 126,500 feet.

Temperatures, after first falling off with height, generally begin to rise at 60,000 feet altitude in the atmosphere.

The successful balloon flight marked a forward step in NASA's program to define experiments for manned, earth-orbiting missions in the Apollo Applications Program. Such short-term testing could help fill gaps in the detailed data needed for more accurate weather forcasting.

The experimenters believe they have successfully completed Phase I of the Apollo applications project--namely, the verification of the instruments and techniques needed to measure vital constituents of global weather.

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FOR RELEASE: THURSDAY, OCTOBER 31, 1968

PASADENA, Calif.--An early page in the brief history of rockets, missiles and space flight in the United States will be observed today with the placement of a historical marker at the Jet Propulsion Laboratory of the California Institute of Technology.

"On October 31, 1936, at a site approximately 400 yards to the southeast, in the Arroyo Seco, a group of students and co-workers . . . fired their first rocket motor . . ." the plaque reads in part.

The students cited in bronze studied at the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT) and were encouraged in their experimentation by the GALCIT Director, the late Dr. Theodore von Kármán.

With the test firing of the rocket engine 32 years ago, Caltech became the first American university to actively sponsor rocket research. The work soon after gained government sponsorship and eventually--in 1944--led to establishment of the Jet Propulsion Laboratory. Clark

Unveiling of the marker is scheduled for 2:00 p.m. in the mall near JPL's main gate. The ceremony will be presided over by JPL Director Dr. William H. Pickering and Caltech President Dr. Lee A. DuBridge.

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Site of the actual firing of the methyl alcohol-gaseous oxygen engine three decades ago was just outside the present boundaries of the 165-acre Laboratory. The river bed location was chosen because of its remoteness from habitation, yet accessibility to Caltech.

Five of the seven men who participated in the first rocket test will attend the ceremony. They are:

Dr. Frank J. Malina, who was JPL's first director and who now resides in Paris, France, where he is a noted painter and founder-editor of LEONARDO, International Journal of the Contemporary Artist.

Edward S. Forman, a research specialist in engineering advanced design at the Lockheed Missile and Space Company, Sunnyvale, California.

William C. Rockefeller, of La Jolla, California., vice president of Sonico, Inc., in San Diego.

Dr. William A. Bollay, of Santa Barbara, California, professor of aeronautics and consulting engineer.

Apollo M. O. Smith of San Marino, California, assistant chief of aerodynamics research at the McDonnell-Douglas Corporation, Long Beach, California.

Unable to attend is Carlos C. Wood, chief engineer of the Sikorsky Corporation's Helicopter Division. He resides in Stratford, Conn. The seventh member of the team, John W. Parsons, died in 1952.

For the occasion, Forman will provide the original engine which will be the heart of a 1968 mockup of the 1936 rocket firing.

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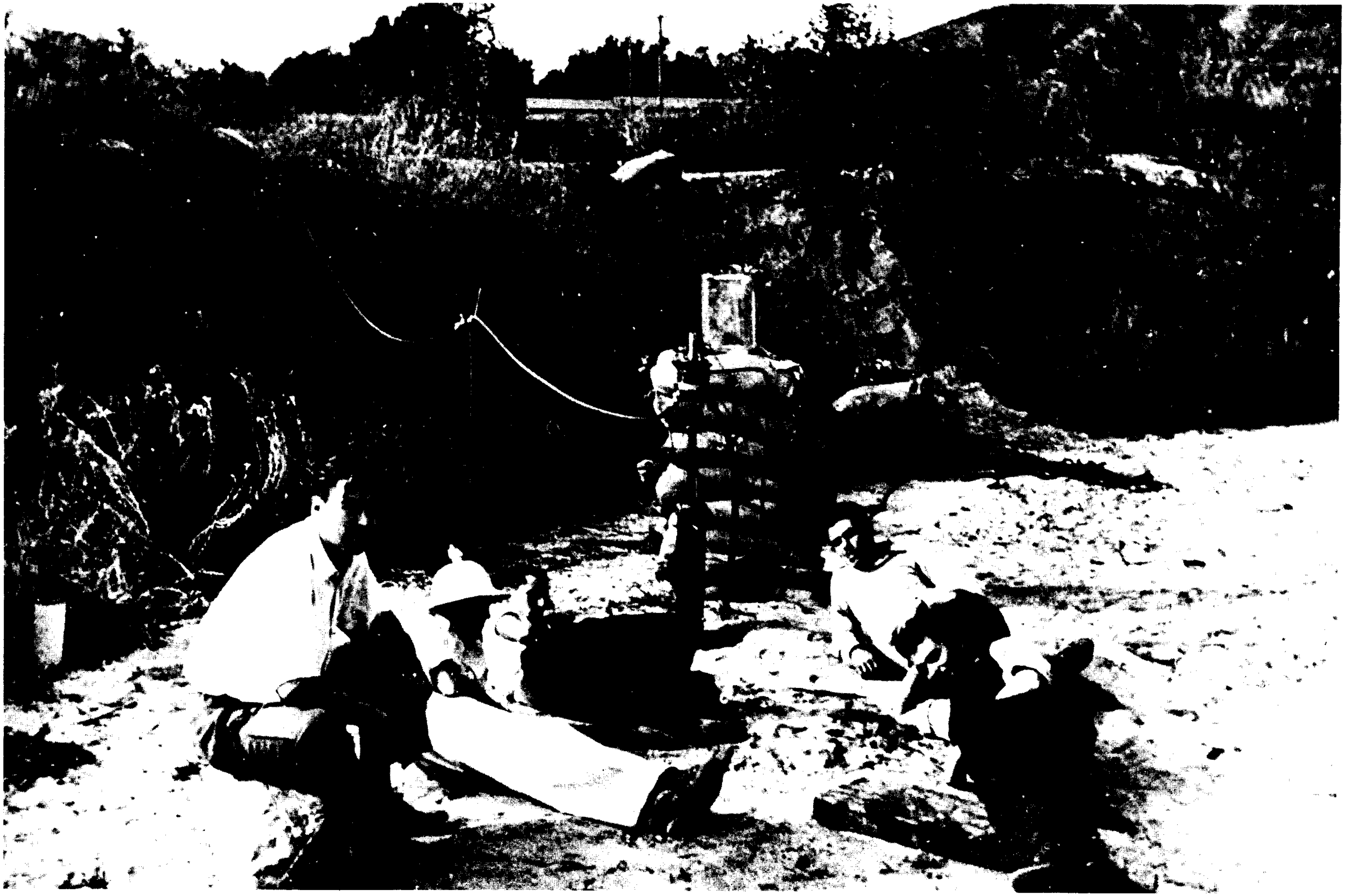
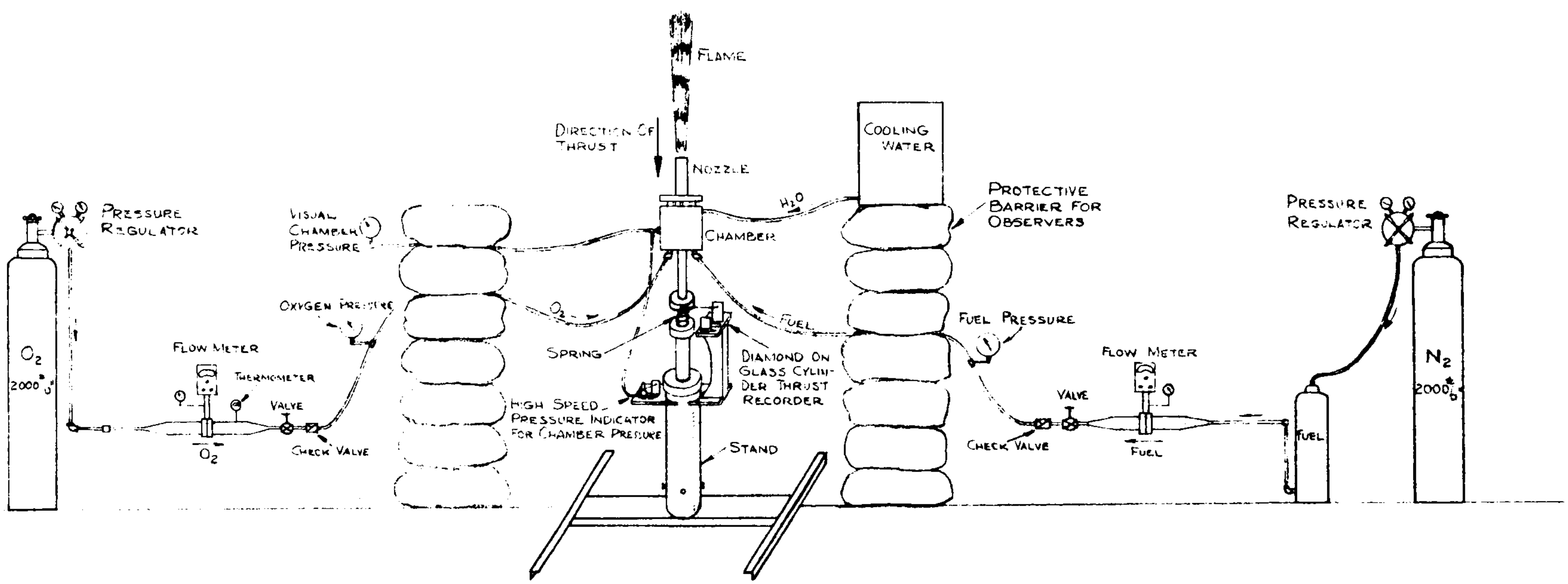
492-10/31/68



P-9007A

This 1936 photograph portrays a few of the members of one of America's first rocket test teams. Some of the group were students at the Guggenheim Aeronautical Laboratory of the California Institute of Technology. GALCIT was the forerunner of Caltech's Jet Propulsion Laboratory. The picture was taken at the site of a rocket test stand in the Arroyo Seco in Pasadena just outside the present JPL boundary. Man at left is unidentified. Others from left are Apollo M. O. Smith; Frank J. Malina, who later became JPL's first director; Edward S. Forman; and the late John W. Parsons.



Schematic Diagram Of Proposed Test Setup For Rocket Propulsive Units Research

Daniel Guggenheim Aeronautical Laboratory
California Institute Of Technology
Drawn By: Frank J. Malina
Date : August 28, 1936

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FOR IMMEDIATE RELEASE: 4/69

Walter H. Padgham has been appointed to fill the new position of Assistant Laboratory Director for Personnel Administration and Supporting Services at the Jet Propulsion Laboratory of the California Institute of Technology according to Dr. William H. Pickering, JPL Director.

Mr. Padgham was formerly manager of the Personnel Administration and Supporting Services Divisions and will continue with the same duties in the new position. He is responsible for the direction of three divisions: Personnel Administration and Security and Plant Protection; Technical Information and Documentation and Fabrication Services.

He joined JPL in December, 1949, as Personnel and Safety Administrator. In 1952, he was named manager of the Personnel and Technical Services Division.

A native of Gooding, Idaho, Padgham was graduated from Pasadena City College in 1934. He attended the University of California at Los Angeles, the University of Southern California and the California Institute of Technology for courses in personnel administration, industrial relations and management.

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Padgham was employed as District Supervisor for the McClintock Corporation from 1936 to 1943 when he joined the California Institute of Technology as Personnel Officer. From 1945 to 1949, he was director of Industrial Relations for the General Tire and Rubber Company.

Padgham is married and resides in Altadena, California.

510-4/10/69

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FOR RELEASE THURSDAY, APRIL 17, 1969

PASADENA, Calif.--Formation of the Viking Orbiter Office at the California Institute of Technology Jet Propulsion Laboratory was announced today by JPL Director Dr. William H. Pickering.

Henry W. Norris was named Viking Orbiter manager; Kermit S. Watkins, deputy manager; Allen E. Wolfe, spacecraft system manager; and Dr. Conway W. Snyder, Viking Orbiter scientist.

The Viking Project, designed to send two orbiters with landing capsules to Mars in 1973, is managed for the National Aeronautics and Space Administration by the NASA Langley Research Center in Hampton, Virginia.

The newly-established office at JPL is responsible for the design and development of the orbiting spacecraft portion of the Viking system and the conduct of the orbiter phase of the mission. The Laboratory is responsible also for Viking tracking and data acquisition.

Norris was JPL's spacecraft system manager for the Mariner Mars 1969 Project. He was named to the Viking position after the successful launch of Mariner VI last February and Mariner VII in March. The two Mariner spacecraft will arrive at Mars in July and August, respectively.

Watkins was assistant project manager for the Surveyor series of lunar soft-landing spacecraft and general manager of project operations for the Laboratory's Office of Flight Projects.

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Wolfe was spacecraft system manager for the Ranger series of lunar photo-reconnaissance spacecraft and for the Mariner V mission to Venus in 1967. His most recent post was manager of JPL's Space Sciences Project section.

Dr. Snyder was project scientist for the Mariner V Venus mission in 1967. He also was a science investigator for solar plasma instruments flown to Venus in 1962 by Mariner II and to Mars in 1965 by Mariner IV.

The two Viking Orbiter spacecraft will circle Mars in 1973 while the Viking Landers descend to the Martian surface.

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512-4/14/69

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FOR RELEASE PM's OF FRIDAY, APRIL 25, 1969

Six new mascons--mass concentrations of dense material--have been discovered beneath the surface of the moon by researchers at the Caltech Jet Propulsion Laboratory.

The recently-discovered mascons, which cause changes in the velocity of moon-circling spacecraft, bring to 12 the total now mapped on the near face of the moon and on its leading and trailing edges as seen from Earth.

Mascons are expected to shed new light on questions of the moon's origin and evolution. Refinement of the lunar gravity model, based on the mascon discoveries, is of interest to Apollo navigation.

The new information was reported today by William L. Sjogren, Paul M. Muller and Dr. Peter Gottlieb of JPL at the 50th annual meeting of the American Geophysical Union at the Sheraton-Park Hotel in Washington, D. C. Their presentations were given at a special session on lunar gravity.

The first six mascons, discovered last year by Sjogren and Muller, also of JPL, are centered beneath the large ringed maria (seas)--Imbrium, Serenitatis, Crisium, Nectaris, Humorum and Aestauum.

Using radio tracking data from the NASA Lunar Orbiter V mission in 1967-68, they plotted the spacecraft accelerations on a moon map and found that the speed increased over each of the circular seas.

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Sjogren and Dr. Gottlieb reported on the continuing analysis of the Lunar Orbiter V data as well as the corroborating results from Lunar Orbiters III and IV.

A map of the moon's gravity field now includes mascon locations, also on the side facing Earth, at Grimaldi, Mare Humboldtianum, and at two unnamed mare areas at 27° E. Long., 5°S. Lat.; and 70° E. Long., 15° S. Lat. Large concentrations of mass are associated also with the partially visible, multi-ringed Mare Orientale on the western limb of the moon and Mare Smythii on the eastern limb.

Again, each mascon was found to be centered below a ringed sea or an ancient, now obliterated, circular sea.

No information is available concerning possible mascons on the moon's backside because orbiting spacecraft cannot be tracked while the moon blocks it from the view of Earth antennas.

Dr. Gottlieb also gave the results of a preliminary study on a revision of the lunar gravimetric model to accommodate the now-known existence of mascons.

Beginning with the qualitative map provided by Sjogren and Muller, the study seeks to obtain a more quantitative estimate of mascon sizes and depths and to estimate the magnitudes of lesser gravitational features.

Dr. Gottlieb said the latest gravity model produces a significant agreement with the analysis of tracking information from the manned Apollo 8 mission last December.

(Noticeable acceleration variations were seen in the Apollo 8 tracking data as the moon-orbiting three-man spacecraft overflew several of the mapped mascons.)

The JPL researchers are working with the NASA Manned Spacecraft Center in Houston in an effort to predict accurately landing sites several orbits prior to landing.

Most of the data available today was taken from spacecraft orbiting the moon at closest altitudes of about 60 miles. The JPL team anticipates new and possibly higher resolution data from Apollo 10 next month when the Lunar Module orbits at a much lower altitude.

The five Lunar Orbiter flights were conducted by the NASA Langley Research Center in Hampton, Virginia. The tracking data was provided by the NASA-JPL Deep Space Network.

The work that resulted in the mascon discoveries followed earlier selenodesy experiments on previous Lunar Orbiter missions by investigators at Langley and JPL.

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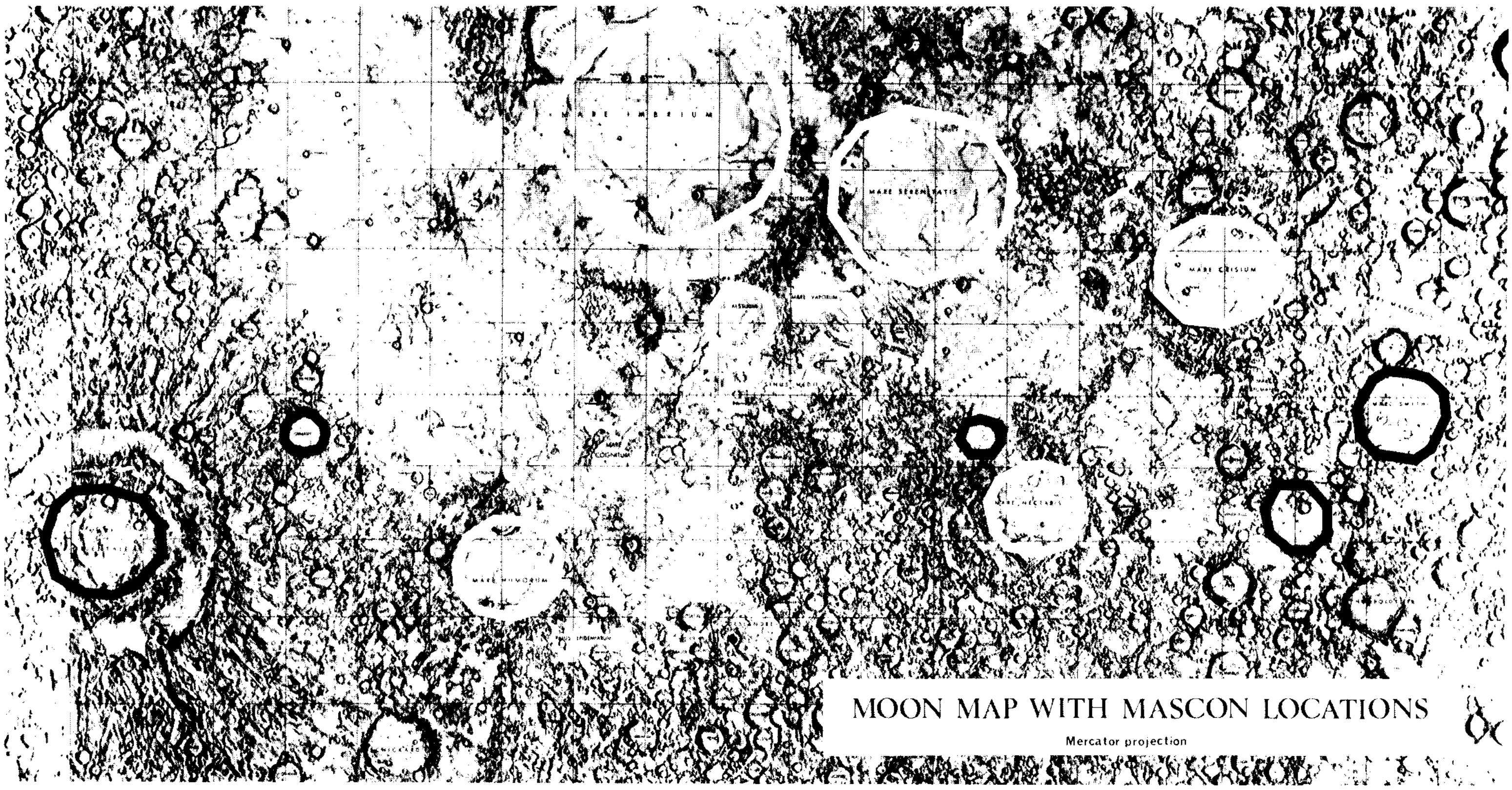

P-9411

Mercator projection of the moon shows the location of 11 mascons--mass concentrations of dense material--discovered by Jet Propulsion Laboratory mathematicians through the analysis of tracking data from the Lunar Orbiter missions. A 12th mascon, at Mare Humboldtianum in the upper right quadrant of the moon, is not inscribed on this projection. The original six mascons are identified by white circles while the newly-discovered lunar gravitational highs are ringed in black.

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FOR RELEASE PM's OF MONDAY, APRIL 28, 1969

The theory that lunar features may have been cut by ocean waves and meandering rivers has been rekindled by the recent discovery of mass concentrations of dense material, or mascons, beneath the surface of the moon, an audience attending an American Physical Society meeting in Washington, D. C., was told today.

Paul M. Muller of the Caltech Jet Propulsion Laboratory said it is now clear that mascons, gravity highs located in depressed lunar basins, show that the moon's internal strength is holding up extra deposited mass. Only the method of transportation of that mass, he said, remains a mystery.

Muller, co-discoverer of the mascons with William L. Sjogren, also of JPL, reviewed their analysis of radio tracking measurements that indicated velocity changes in the moon-circling Lunar Orbiter spacecraft and led to the construction of a gravimetric map of the moon's near side.

Addressing an APS session at the Sheraton-Park Hotel devoted to "The Moon," Muller said the mascons, representing local high-gravity areas, correlate one-for-one with lunar ringed seas, which are depressed basins, or with ancient, now obliterated, circular seas.

He said the mascons might be excess mass deposited by water and supported by the internal strength of a rigid moon.

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Among other theories, Muller said, is that which holds the ringed seas were formed by lava flows released from deep within the moon when the lunar crust was broken by tremendous impacts. Still others include dry transportation, meteoritic erosion and multi-stage lava processes.

He quoted the theory advanced by Dr. John Gilvarry of the Rand Corporation that the mascons are water deposited sediments similar to Earth garden soil. This could account for the existence of a large gravitational bump over a deep basin, he noted, pointing out that the ringed seas overlying the mascons are deep basins.

Muller said the mascons, then, probably are not floating on a liquid lunar interior as are the continents and mountains of the Earth, but are instead held there by a moon with structural strength.

Using high-resolution moon photos taken by the series of NASA Lunar Orbiter spacecraft and Apollo 8, Muller illustrated the theory for primordial lunar water by pointing out moon features that include possible beaches, ice or water-cut rilles, seashore features, broken craters and ghost craters.

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515-4/23/69

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FOR RELEASE: SUNDAY, MAY, 4, 1969

(Editors: This story on the Infrared Radiometer is the first in a series on the scientific experiments aboard Mariner spacecraft at Mars this summer.)

PASADENA, Calif.--How cold is Mars? Is it twice as cold as Earth? Are its poles capped with water ice or dry ice?

The infrared radiometers aboard both Mariner '69 spacecraft should produce important answers. The small, delicate instruments, coordinating with the TV cameras, will measure the thermal radiation--i.e., heat--of the Martian surface from South Pole to well north of the Equator, and on the night side as well as the sunlit side of the planet.

The infrared radiometer (IRR) is designed to measure temperatures from 270 degrees below zero to 80 degrees above zero, Fahrenheit. But Caltech and Jet Propulsion Laboratory scientists don't expect many above-freezing readings.

A principal goal of the IRR is to determine whether the Martian south polar cap is frozen carbon dioxide or frozen water. If, as seems indicated by some previous studies, it is carbon dioxide, the mass would be dry ice, about -200 degrees, F., or colder.

However, polar temperatures of -170 degrees or warmer would imply water ice is present.

Earth studies and Mariner IV fly-by experiments in 1965 indicate carbon dioxide is the main element in Mars' atmosphere, with little oxygen or hydrogen present.

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The two '69 spacecraft are scheduled to fly by Mars in August at a nearest approach of 2,000 miles. In 1964, the closest distance was 6,100 miles. The Mariner spacecraft were built by JPL for the unmanned program of the National Aeronautics and Space Administration. Caltech operates JPL for NASA.

Dr. Gerry Neugebauer, Caltech physicist, is the principal investigator for the IRR experiment, with Stillman Chase, of the Santa Barbara Research Center, and Dr. Guido Munch, Caltech astrophysicist, co-investigators. The instrument was designed by Chase and his Santa Barbara staff. Ellis D. Miner is JPL cognizant scientist and Don Schofield, JPL cognizant engineer, for the experiment.

The experimenters hope to produce the most comprehensive thermal profile yet obtained of another planet.

The sensitive radiometer is bore-sighted with the TV camera to synchronize surface temperature readings with areas shown in each picture as the spacecraft sweep past Mars. The IRR will operate in "real time," taking temperatures and transmitting them to Earth immediately.

The radiometer weighs only 7.5 pounds, measures 3 x 6 x 9 inches overall, and requires but three watts of power. Yet here is what it does:

Using miniature twin-channel telescopes, the instrument will receive and measure the intensity of the radiation emitted by the Martian surface. All matter radiates energy, the amount varying with temperature and wavelength.

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The light energy is reflected by a mirror through lens and filter arrays in each channel. The filters stop all but selected wavelengths of infrared light. The desired wavelengths are between 8 and 12 microns in one channel, and 18 to 25 microns in the other. (A micron is 1/1,000th of a millimeter, or 1/25,000th of an inch.)

The lenses focus the desired rays onto detectors, which are thermopiles made of antimony-bismuth. The detectors convert the energies into voltages and relay them to an electronics unit. This equipment, in turn, translates the voltages into pulses for radio transmission to JPL monitoring stations on Earth.

The radiometer will start taking temperatures on Mars' sunlit side within three days of each spacecraft's encounter with the planet. Measurements will cover virtually the entire visible surface of the planet.

However, best results are anticipated in the half-hour of closest approach when the Mariners sweep past the sunlit side, across the sunset line, and around to the night side of Mars. Temperature readings are set for one every two seconds, and should reveal day and night variations.

Most of the temperature data will be transmitted to the Goldstone Tracking Station near Barstow, Calif. Goldstone, with its 210-foot antenna, is the heart of the worldwide Deep Space Network which JPL operates for NASA.

There is a possibility that the IRR may also reveal what temperature variations exist in the "wave of darkening" that moves across the face of Mars every six months.

Some scientists theorize that this darkening from pole to equator, which appears to be maximum at the summer solstice, is the best evidence there may be life on Mars. There was once speculation that the darkening might be vegetation until Mariner IV pictures showed only ancient, barren terrain with no apparent life.

The 1969 mission planners do not--repeat not--anticipate finding any direct evidence of life. However, the general goal is to take a closer look at the Martian environment and establish a basis for future experiments which may concentrate on the search for life on that planet in the next decade.

Dr. John A. Stallkamp is JPL project scientist for the Mariner '69 program. Harris M. Schurmeier is project manager for JPL.

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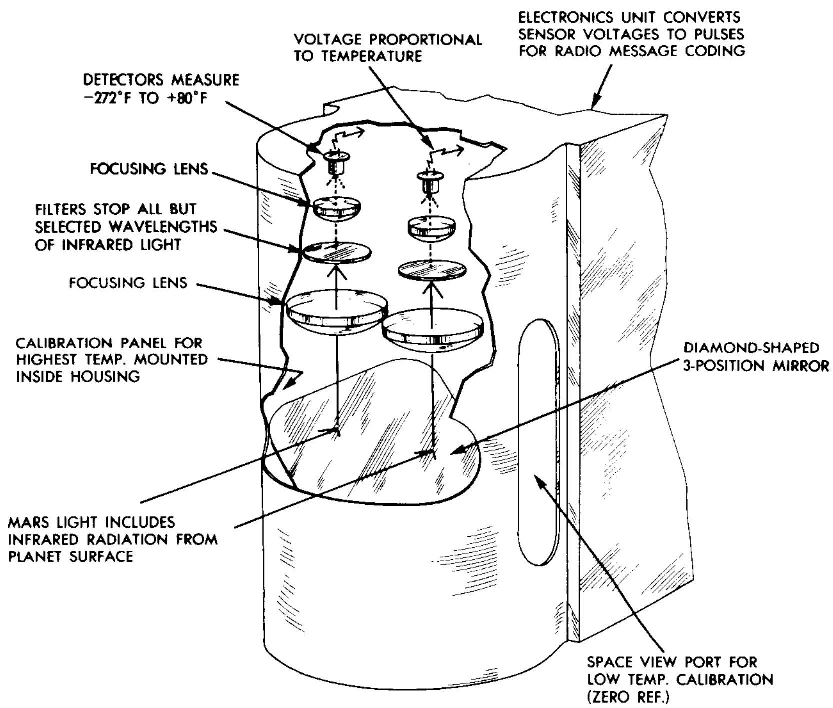
BB-516-4/28/69

MARS THERMOMETER: This little box, called an infrared radiometer, is part of the scientific equipment aboard each of the Mariner '69 spacecraft. It is specially designed to measure thermal radiation, and hence, the temperatures, of Mars as the spacecraft fly within 2,000 miles of the planet late in July and early August. A research assistant at Caltech's Jet Propulsion Laboratory holds the instrument, working details of which are illustrated in the accompanying diagram. The radiometer weighs only 7.5 pounds, and is 3 x 6 x 9 inches in size. The Mariner '69 project is being conducted by JPL for the National Aeronautics and Space Administration.



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FOR RELEASE: AM's OF SUNDAY, MAY 11, 1969

PASADENA, Calif.--Dr. William H. Pickering, Director of Caltech's Jet Propulsion Laboratory, today announced the appointment of Dr. Robert J. Mackin Jr. to the post of manager of JPL's Space Sciences Division.

Dr. Mackin succeeds Dr. Donald P. Burcham who has been named research and advanced development manager for space science in the Laboratory's Office of Research and Advanced Development.

A native of Little Rock, Arkansas, Dr. Mackin was graduated from Yale University in 1949 with a Bachelor's degree in electrical engineering. He received his M.S. degree in 1951 and Doctorate in physics in 1953, both from the California Institute of Technology.

Dr. Mackin joined JPL in 1962 as manager of the Physics Section. He has served as manager of the Lunar and Planetary Sciences Section and Space Sciences Division representative for research and advanced development.

Prior to joining JPL, he was with the Office of Naval Research, Washington, D. C., 1954-56, and the Controlled Thermonuclear Division, Oak Ridge National Laboratory, 1956-62. Dr. Mackin has authored numerous articles on experimental nuclear physics, plasma physics and controlled thermonuclear research, and a book on planetary science.

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Dr. Burcham, a native of Portland, Oregon, was graduated from Reed College, Portland, in 1937, with a bachelor's degree in physics. He earned his Ph.D. in physics at the University of Washington in 1942.

Before joining JPL in 1963, Dr. Burcham was with the U. S. Navy Bureau of Ordnance, University of Washington Applied Physics Laboratory, National Bureau of Standards and Emerson Research Laboratories. He was president and board chairman of Aerolab Development Company of Pasadena, Calif., from 1961 to 1963.

Dr. Burcham managed advanced Mariner projects for JPL and the Advanced Planetary Missions Technology Office. More recently he has served as deputy manager and manager of the Space Sciences Division.

Dr. Mackin, father of two, resides in Pasadena. Dr. Burcham, his wife and two children live in La Canada, Calif. The Burchams also have a married daughter and a grandchild.

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517-5/6/69

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FOR RELEASE TUESDAY, MAY 27, 1969

DECEPTION ISLAND

PASADENA, Calif.--Life overcomes lava, but it is a slow process, a soil scientist of Caltech's Jet Propulsion Laboratory verified this week in a report on volcano-torn Deception Island.

During a six-week field trip to the Antarctic island, Dr. Roy E. Cameron found that algae, fungi and tiny bacteria were beginning to grow within a year or 13 months of heavy earthquake and volcanic action.

Cameron and Dr. Robert Benoit found the microscopic evidence in the lava rubble near the center of the small island which was rent by volcanic blasts on Dec. 4, 1967.

And they got out with the evidence just in time. Shortly after the scientists left last February, the island was hit by a new eruption which forced evacuation of British and Chilean exploration bases.

Deception Island, only 8 by 10 miles in dimension, is at the tip of the Antarctic Peninsula which extends to within 1,000 miles of the southern tip of South America. Argentina also maintains a weather station and scientific base on the international island.

Cameron and Benoit, a biologist from Virginia Polytechnic Institute, brought back 19 samples of Deception Island soil with microorganisms of some sort. Eight ounces of each sample are under culture to see what develops in JPL's soil science laboratory.

This was Cameron's third field trip to the Antarctic. His previous efforts have been to collect frozen soil samples to determine possible life forms on Mars, which is believed to resemble Antarctica.

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Cameron reported there was no visible plant life growing on the volcanic slopes, but marine algae were found within the three main craters on the island. Most of the viable samples were gathered from around fumaroles (steam vents), where temperatures of 170 to 210 degrees, Fahrenheit, were registered.

These contained minute, colored bacteria called thermophiles or actinomycetes, which adapt well to high temperatures.

The scientists made other interesting observations. Despite generally freezing air temperatures, the waters around the island still boiled occasionally. Petrels were observed hovering and plunging into the sea for a dinner of nature's home-cooking--fried shrimp.

A few Weddell seals frequented the beaches. Their coats were yellowed by the sulfurous water. Chin-strap and Gentoo penguins were found with blistered feet.

Cameron and his co-investigator also collected gas samples and made temperature, humidity, wind and solar radiation measurements in their six weeks in the caldera, or volcanic heartland, of the lonely island. Winds reached velocities of 65 to 90 miles per hour.

The 1967 volcano-earthquake pushed up an oval-shaped island of cinder cones in Deception's center which the Chileans named "Yelcho" after the vessel which evacuated them following the eruption. Cameron describes the inner island, a 3/4-mile strip in a semi-lagoon, as "a lunar-like terrain of cinders, ash and crumbly lava."

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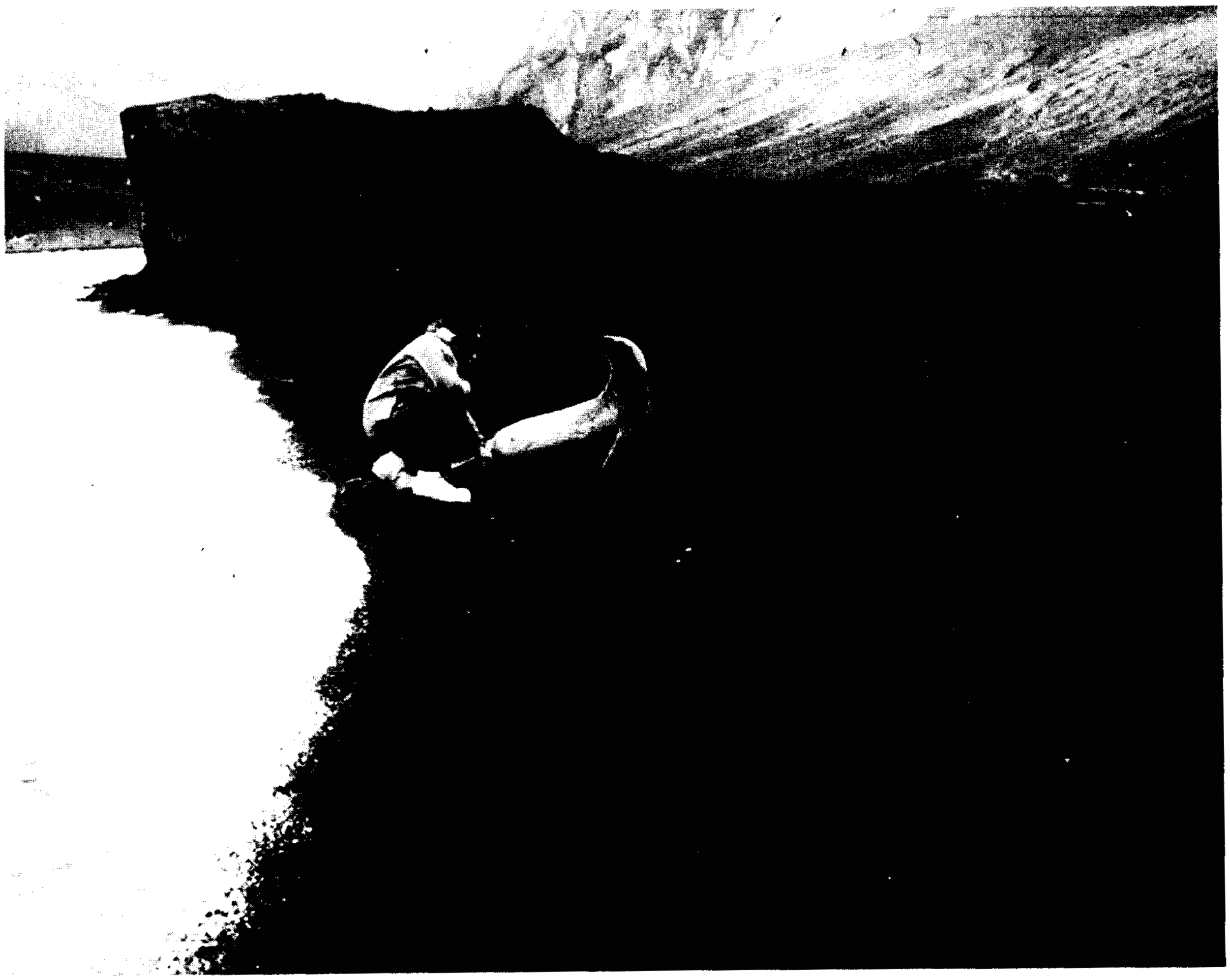
This research trip was sponsored by the National Science Foundation. The investigators were taken to the island by the research ship RV Hero, operated by the NSF. The NSF also furnished a microbiological laboratory. While on the island, the scientists lived in an abandoned whalers' hut.



LIFE GOES ON: Despite volcanos, Weddell seals still continue to make Deception Island, on the fringe of Antarctica, a calling station. Dr. Roy E. Cameron of Caltech's Jet Propulsion Laboratory who took this picture, found life goes on despite lava. Shown here is Dr. Robert Benoit, of Virginia Polytechnic Institute, Cameron's co-investigator of life forms in Antartica. Their studies are connected with JPL's continuing comparison with possible life on harsher planets for the National Aeronautics and Space Administration. The Deception trip was sponsored by the National Science Foundation.

BB-519-5/22/69

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FOR RELEASE: SUNDAY, JUNE 1, 1969

Two Mariner spacecraft enroute to Mars logged a combined total of 272,363,358 miles of space travel at noon today with 167 million miles--and 8 weeks--to go to Mars encounter.

Mariner VI is 21,731,091 miles from Earth and will fly past Mars--at its point of closest approach--at 10:18 p.m., PDT, July 30, after traveling 241,838,160 miles since launch last February 24.

Mariner VII is 19,526,893 miles from Earth and will fly past Mars at 10:00 p.m., PDT, August 4. Its total travel distance will be 197,137,830 miles. At noon today it had covered 110,808,438 miles since launch on March 27.

The distance from Mars to Earth at encounter will be approximately 60 million miles.

Each of the 850 pound spacecraft are identically equipped with two television cameras to photograph Mars at medium and high resolution and with instruments to measure the temperature of the surface and to determine the composition of the upper and lower atmosphere. Atmospheric density will also be measured by transmitting the spacecraft radio signal through the atmosphere of Mars as the spacecraft curves behind the planet.

The first data on Mars will be transmitted to Earth on the night of July 29 in the form of 33 pictures of the full disc

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of the planet taken by Mariner VI during its approach to Mars.

The pictures will be stored on a tape recorder in the spacecraft and played back when Mariner VI is over the 210-foot diameter communications antenna at the Goldstone station of the Deep Space Net in the California Mojave desert. (Additional pictures are then recorded on the tape.) Use of the sensitive 210-foot antenna will allow transmission of one picture each five minutes at a rate of 16,200 bits per second. By comparison it required 8½ hours to transmit each picture from Mars in 1965.

The two spacecraft are programed to return a total of 141 pictures of the disc of Mars in five transmission sessions as they approach Mars. When the spacecraft fly past Mars the tape recorders will then store 24 surface pictures for each spacecraft and science data from the other instruments. These will be transmitted to Earth when the spacecraft have gone beyond Mars.

The 1965 pictures contained 240,000 bits each compared with 3,900,000 bits for the pictures expected from the current missions.

521-5/29/69

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FOR RELEASE SUNDAY, JUNE 15, 1969

(Editors: This story on the Ultraviolet Spectrometer is another in a series on the scientific experiments aboard Mariner spacecraft at Mars this summer.)

PASADENA, Calif--Did Mars evolve like the Earth and how old is the red planet?

These questions may be answered in part by the ultraviolet spectrometer instruments aboard the Mariner '69 spacecraft headed for Mars and light wavelength tests of that planet's upper atmosphere late in July and early in August.

The instruments are designed to identify gases in regions 60 to 600 miles out from Mars, with a closest approach by the spacecraft of about 2,000 miles from the planet. The ultraviolet spectrometer (UVS) identifies molecules, atoms and ions by the wavelengths of light that they absorb or emit. Ions are molecules or atoms that have gained or lost electrons--that is, charged particles.

Mariner scientists hope that identification of gases--principally oxygen, nitrogen, and perhaps hydrogen--may help to determine whether the Martian atmosphere resulted from condensation of solar material, or from gases released by the planet itself, or a combination of the two processes.

The composition and origin of the upper atmosphere could provide clues to the age and evolution of the planet, Dr. C. A. Barth, of the University of Colorado, says. Dr. Barth is the principal investigator for the UVS experiment, one of several Mariner scientific probes designed for NASA by Caltech's Jet Propulsion Laboratory.

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Ultraviolet studies of Mars have not been made from Earth because ultraviolet rays cannot penetrate our atmosphere. Brief studies have been made above the atmosphere from balloons and sounding rockets. The 1969 mission marks the first attempt to use a UV spectrometer to identify gases around Mars.

After Mariner IV's 1965 photographs of Mars, scientists tend to believe that the planet is older and much drier than Earth. Study of the atmosphere by both ultraviolet and infrared spectrometers aboard Mariner '69 spacecraft can aid in determining the environment in which life forms, if present on Mars, would have to exist.

The UV spectrometer will measure the amount and distribution of atomic and diatomic elements in the upper atmosphere--with particular stress on compounds containing carbon, oxygen, nitrogen and hydrogen.

Hydrogen and oxygen atoms can be identified only by ultraviolet light, which has a shorter wavelength than infrared.

Ozone, Barth feels, may be the key to the riddle of evolution of life on Mars. The presence of this oxygen-bearing gas above craters or lowlands, he says, would indicate probable presence of oxygen molecules. The UV spectrometer is so sensitive that it can detect ozone down to one-thousandth of the amount found in Earth's upper atmosphere.

A lack of oxygen would force any forms of life on Mars to develop some means of obtaining oxygen other than from the atmosphere. If there is no ozone layer such as Earth has, to filter out deadly ultraviolet wavelengths, living organisms would need special protective devices, or have to live underground.

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The distribution of atomic hydrogen and water vapor also will be an important measurement of the UV instrument. On Mars, Barth points out, the release of water vapor may be controled by melting of the polar ice caps, even though they appear to be carbon dioxide. The investigator believes it probable that hydrogen atoms will be found in the thermosphere--the 60 to 300-mile range above Mars.

The rate of evaporation on Mars--slight as it may prove to be--can be determined by the density and temperature of the thermosphere, Barth adds. The UV spectrometer is designed to provide such data, plus information on atomspheric pressure, the amount of charged particles striking the planet's surface, and the intensity of the Martian dayglow.

If the atmosphere of Mars is the remnant of a primordial gas that formed the solar system, it would contain only about 15 per cent nitrogen compared with the 78 per cent found in Earth's atmosphere, Barth says. Moreover, if Mars has outgassed or erupted from the interior as Earth has, it may have as little as 7 per cent nitrogen, he adds. That, too, could account for the bulk of the atmosphere being carbon dioxide, as appears to be the case.

A deficiency of nitrogen would make it difficult to form amino acids considered necessary to originate life as we know it here on Earth.

The atmospheric density may be best measured in the twilight zone as the Mariners fly past the sunset (terminator) line on Mars. The amount of light reflected beyond the terminator could indicate the density of the planet's lower atmosphere.

Such data would complement the Mariner radio signal occultation test, designed to refine the 1965 figures for Mars' surface pressure and altitudes. Mariner IV radio occultation experiments indicated Mars has a very thin atmosphere, with a surface pressure of 4 to 10 millibars, only 1/100th that of Earth. Scientists believe that carbon dioxide is the most abundant element in the Martian atmosphere.

The ultraviolet spectrometer will start looking at Mars' atmosphere in the 600 to 625 mile range above the planet as near encounter begins. As the Mariners fly closer, the instruments will measure the ultraviolet light from the air down to within 60 miles of the Mars surface.

The UV spectrometer weighs 35 pounds and uses 15 watts of power. It was built for JPL and NASA by the Laboratory for Atmospheric and Space Physics, University of Colorado. Dr. Barth is scientific director of the Colorado laboratory.

The spectrometers were designed by Kermit Gause, chief engineer of the Colorado laboratory. Each instrument was ground out of a solid 145-pound block of aluminum and carefully machined over a 20-week period.

Each instrument employs a small telecope, focusing mirrors, slits and microscopically grooved gratings that diffract incoming light into separate, ultraviolet wavelengths. There are 2,160 rules or line per millimeter on these moving gratings.

Each spectrometer has two detectors--acutely sensitive photo-mulitplier tubes designed to record wavelengths in the 1100 to 2150 and the 1900 to 4350 angstrom regions. (An angstrom is 10/1,000,000th of a millimeter.)

The detectors convert the light impulses to voltages, which are processed and stored by an on-board tape recorder for transmission to Earth. Some data will be transmitted during the encounter phase of the mission but most of it will be radioed back later

Dr. Barth's co-investigators are William G. Fastie, Johns Hopkins University; Gause, Fred C. Wilshusen, Ken Kelly, Ray Ruehle, Jeffry B. Pearce, Charles W. Hord, all University of Colorado; and Edward F. Mackey, Packard-Bell Electronics. The JPL experiment representative is Odell Raper.

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BB-523-6/11/69

PHOTO CAPTION P-9455

FINE-TUNED FOR MARS: This ultraviolet spectrometer, which will identify gases in the Martian atmosphere this summer, undergoes inspection in the University of Colorado's Laboratory for Atmospheric and Space Physics prior to installation on Mariner VI and VII spacecraft. At right is Dr. C. A. Barth, laboratory director, who heads the UV spectrometer experiment for the National Aeronautics and Space Administration's 1969 Mars project, conducted by Caltech's Jet Propulsion Laboratory. At left is James D. Cunningham, engineering director of the Colorado laboratory which machined the instrument out of a solid 140-pound block of aluminum similar to the one shown here.

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FOR RELEASE THURSDAY, JUNE 26, 1969

Dr. William H. Pickering, director of the California Institute of Technology Jet Propulsion Laboratory today announced the appointment of Dr. Clarence R. Gates as manager of JPL's newly-established Mission Analysis Division.

The new division initially will be comprised of the existing Systems Analysis and Systems Analysis Research sections and the JPL Navigation Program which Dr. Gates headed since it was established last year.

Tom W. Hamilton has been named to succeed Dr. Gates as manager of the JPL Navigation Program.

The division will develop and apply modern systems analysis technology to a wide range of areas, and will continue the space navigation and celestial mechanics efforts of the Laboratory.

Dr. Gates, a native of Illinois, was graduated from the University of Oklahoma in 1947 with a Bachelor's degree in electrical engineering, and received his Ph.D. in electrical engineering and mathematics from Caltech in 1951. His research at Caltech was performed under Dr. Pickering.

Dr. Gates joined JPL in 1950, and his activities there have included reliability, communication theory, missile guidance, space navigation, spacecraft design, and systems technology. He has lectured and published extensively in the fields of space guidance and applied celestial mechanics.

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Prior to his current appointment Dr. Gates has been manager of the Systems Analysis Section, manager of the JPL Navigation Program, and manager of the Systems Division.

Hamilton joined JPL in 1952 immediately following his graduation from Caltech where he was awarded the Bachelor's degree in physics. He has performed guidance and mission analysis for all JPL flight projects for NASA and for missile systems during JPL's association with the U. S. Army.

Hamilton, who was born in Evergreen Park, Illinois, in 1931, had served as manager of the Laboratory's Systems Analysis Section and acting assistant manager of the Systems Division prior to his current appointment.

Dr. Gates, his wife, Betty, and two children reside in Pasadena. Hamilton, his wife and two children reside in Altadena.

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524-6/22/69

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FOR RELEASE SUNDAY, JUNE 29, 1969

(Editors: This story on the Radio Occultation experiment is another in a series on scientific goals of the Mariner spacecraft at Mars this summer.)

PASADENA, Calif.--The atmosphere at the surface of Mars is perhaps as thin as Earth's atmosphere at over 100,000 feet, or 3½ times higher than Mount Everest.

And Mariner '69 scientists at Caltech's Jet Propulsion Laboratory hope to knock the "perhaps" out of that statement--one way or another--this summer. They will use the same experiment--S-band radio occultation--that first produced this surprising data on the Mariner IV flight in 1965.

That experiment fixed Martian surface pressure in the very low range of 4 to 10 millibars. This corresponds with Earth atmospheric pressures at altitudes from 102,000 to 115,000 feet. Atmospheric pressure on Earth's surface is 1,000 millibars. In short, Martian atmospheric density appeared to be only one-hundredth that of Earth.

This year's twin spacecraft radio experiment will try to pinpoint surface pressures, provide new altitude readings, and remeasure the radius of Mars. Both Mariners are scheduled to fly within 2,000 miles of the red planet about August 1.

The 1965 occultation experiments also indicated Mars has mountains. There was a height differential of 16,500 feet (five kilometers) between the southern hemisphere point where Mariner IV passed behind the planet and the northern hemisphere spot it emerged.

Radius of Mars was calculated at 3,384 and 3,379 kilometers at those points. This is about 2,115 miles, or a diameter of 4,230 miles--6/10 that of Earth.

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The manner in which density varied with height indicated the Martian atmosphere was composed predominantly of carbon dioxide. And temperatures near the surface were inferred to be a chilly -35 to -140 degrees, Fahrenheit.

Dr. Arvydas J. Kliore of JPL again heads the Mariner radio occultation team for the National Aeronautics and Space Administration project. He will be assisted by Dr. S. I. Rasool, Goddard Institute for Space Studies; Dr. Gunnar Fjeldbo, and Boris Seidel, both of JPL.

The occultation experiment requires no other instruments than the spacecraft radio and Earth tracking station receivers. It does require a trajectory that passes behind Mars, so that the planet cuts off the spacecraft from the view of the NASA-JPL tracking network.

As each Mariner curves behind Mars, its radio signal will pass through the Martian atmosphere and be cut off at the surface. The signal will reappear 20 minutes later from the first spacecraft and 40 minutes later from the second as each emerges from the Martian shadow.

Each craft will fly 6,000 to 10,000 miles behind the planet after coming within 2,000 miles of the visible face. The 1965 occultation lasted 54 minutes, with Mariner IV swinging 16,000 miles behind Mars after a nearest approach of 6,000 miles.

The atmosphere will refract the radio waves, changing them in frequency and strength. (The spacecraft S-band transmitters operate at a normal frequency of 2195 megacycles.) Measurements on Earth of these changes in the radio signal yield the data on the density and pressure of the atmosphere.

The signal will also be affected by the electron density of Martian atmosphere, which is expected to be up to four times as heavy as 1965 values because of increased solar activity this summer. Electron density in 1965 was found to be one-tenth of the maximum of the Earth's ionosphere.

If both Mariners '69 are succesful, Kliore and his co-experimenters will have four new sets of measurements to compare with 1965 occultation figures. The planned trajectories--one across the equatorial face, the other close to the Martian poles--will provide four points (two entrance, two exit) entirely different from the 1965 entrance and exit sites.

The experiments also should help to determine the oblateness of Mars--that is, how much it is flattened at the poles, like the Earth.

Knowing the atmospheric density of Mars is important to the design of future landing craft. It could resolve, too, questions of what kinds of life, if any, may ultimately be found on the planet.

The tracking of Mariner spacecraft radio signals throughout both flights also will give other JPL scientists a chance to refine planetary data.

This experiment in celestial mechanics--using ground equipment at the various tracking stations--will study the effect of Earth and Mars on the flight paths of the spacecraft to determine more exactly: (1) the mass of Mars, (2) the Earth-moon mass ratio, and (3) the distance from Earth to Mars at each encounter time.

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Encounter ranging information combined with radar bounce data is expected to provide a more accurate determination of the size of Mars. The planet is roughly 6/10 the size of Earth.

Mariner tracking data, when added to radar and optical telescope studies this year, will improve the ephemeris of Mars. A planet's ephemeris is the log of its spatial positions in its orbit around the Sun. JPL is trying to improve the ephemerides (cq) of all planets.

Principal investigator for the celestial mechanics experiment is John D. Anderson of JPL. Co-investigator is Warren L. Martin, also of JPL.

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FOR RELEASE PM's OF FRIDAY, JULY 25, 1969

(Editors: This story on the Television Camera experiment concludes the series on scientific goals of the Mariner spacecraft at Mars this summer.)

PASADENA, Calif.--Some aeons-old secrets of Mars could be unveiled by spectrometers, television cameras and radiometers aboard Mariner VI and VII in the next week or so when the spacecraft fly by the red planet at a distance of only 2,000 miles. Scientists will use the cameras and other experiments to seek hopeful signs of nonlunar developmental processes, including a Martian atmosphere conducive to some form of life.

With twin camera systems capable of taking close-ups 100 times more detailed than Mariner IV pictures yielded in 1965, Caltech and Jet Propulsion Laboratory scientists say this year's television experiment should provide a tentative answer to the riddle: Is Mars geologically alive, sleeping, or dead?

The 1965 Mariner's 21 history-making photographs seemed to put Mars in a class with the Moon--crater-pocked, bleak, barren, and blighting the hopes of biologists. The 1969 Mariners will be able to photograph craters 900 feet in diameter, perhaps canals, if there are any, and any features that might be Earth-like. But Dr. Robert B. Leighton, Caltech physicist-astronomer who is chief investigator for the television experiment, is not optimistic about the latter possibility.

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"From the 1965 photographs, Mars appears fairly dead," says Leighton, who also headed the Mariner IV photo team. "However, we have a minimum of preconceived notions and I'm sure our preconceived notions could be wrong. We are confident that the broader sweep of Mars that will be covered by the Mariner 6 and 7 pictures, and their better definition will reveal many new features and give us new insight as to the nature of that planet."

Another member of the photo study team, Dr. Norman H. Horowitz, thinks the possibility of finding life on Mars is important enough to make the search worthwhile, although the probability may be low. "It is not optimism about the outcome, but the tremendous importance that a positive result would have, that sustains the search," he adds.

Horowitz, chief of the bioscience section at Caltech's Jet Propulsion Laboratory, says this summer's Mariners should provide valuable data for the continuingMars exploration series. Mariner VI is scheduled to sweep by Mars July 30, Mariner VII on August 4. The flybys are conducted by JPL for the National Aeronautics and Space Administration. Caltech operates JPL for NASA.

In 1971, two Mariner-like craft are to orbit Mars and survey it for periods up to three months. Two Project Viking landing capsules are to sample the planet's air and surface in 1974. The Viking orbiter spacecraft will be built by JPL, the landers by NASA's Langley, Va., Research Center.

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If all goes well, the '69 Mariners would take up to 191 pictures, ranging from full-disc portraits to overlapping closeups. Under maximum conditions, Mariner VI will be asked to take 50 long shots, starting 48 hours before close encounter, and Mariner VII will be set for 93 long shots, beginning 72 hours out. If conditions appear less favorable, each spacecraft will take only eight long shots. These will be taken with a telescopic lens capable of reading an auto license plate three miles away.

Each spacecraft is scheduled to take 24 closeup shots, alternating its pair of cameras--a wide-angle lens with a resolution of two miles, and the telescopic lens which will record features 900 feet across from the fly-by distance of 2,000 miles.

Mariner VI is concentrating on an equatorial belt roughly 90 degrees east of the 1965 photo path. Mariner VII will concentrate on a South polar fly-by, although overlapping the Mariner VI path over the Meridiani Sinus, a permanent dark area near the Equator.

What are the cameras and spectrometers shooting for? All types of classical Martian features about which conjecture has swirled. Polar caps, "blue" maria, white and blue clouds, dark and light changeable areas, "canals," and the specific size, structure and distribution of craters and other surface relief.

Sharper photos, combined with readings by infrared and ultraviolet spectrometer instruments and an infrared radiometer, could narrow the question of what kind of life, if any, could exist, on the planet. In addition, the '69 Mariners should provide the basis for the most thorough mapping of Mars yet accomplished.

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Mariner IV photos covered 600,000 square miles, or one per cent of the surface. This time, far encounter photos should cover all of the planet as it rotates at least twice for each set of cameras. (Mars rotates every 24 hours, 37 minutes--an Earth day with a little solar overtime.) Closeups will be made of about 20 per cent of the surface.

The 1965 photos showed some 300 craters extending in a swath from about 50 degrees north latitude to 50 degrees south latitude. They ranged in diameter from 1 3/4 miles to 110 miles. If the rest of Mars is like that, scientists estimate the planet may have as many as 30,000 craters, compared to Earth's handful.

Mariner IV also detected some linear markings tenatatively called "crust fractures," perhaps 100 to 200 miles long and several miles wide. But Dr. Leighton does not believe these are the so-called "canals" of popular fame. An Italian astronomer, G. V. Schiaparelli, first labeled certain long, fine markings "canali" in 1877. "I am open minded concerning the existence of these 'canals' on Mars," says Leighton.

Nor did Mariner IV find any mountain chains, great valleys, ocean basins or continental masses, or similar Earth-like features. Leighton is hopeful that Mariners VI and VII will disclose significant differences in erosion over Mars' surface. It would be most fascinating to find evidences of water erosion from ancient oceans, but he rates the chance of finding any large bodies of water today at "absolutely zero." However, he foresees "a good possibility that there are sizeable bodies of permafrost"--somewhat on the order of Antarctica or Greenland--in the polar regions.

Following the 1965 photos, Leighton and co-investigators estimated the Martian surface could be 300 million to perhaps 5 billion years old. The prevalence of craters signifies an extremely slow rate of surface erosion as compared to Earth. In fact, the door is not shut on the possibility that the Mars surface could be in a primitive form which might yet yield clues to organic development that have long since disappeared from Earth.

Most people regard Mars' white polar caps as proof of the existence of large amounts of water on the planet. However, Leighton and another co-investigator, Dr. Bruce Murray of Caltech, believe the polar caps are dry ice, frozen carbon dioxide, 260 degrees below zero, F., rather than water ice, -170 degrees or warmer. Carbon dioxide is believed to be the main constituent, with little oxygen or hydrogen present, in the Martian atmosphere. Maximum temperatures at Mars' equator may be as high as 68 degrees above zero, F.

While encounter time is midsummer on Earth, it will be fall in Mars' northern hemisphere, spring in the southern half, roughly corresponding to October 15 here.

The photo experiment shares several scientific tasks with other Mariner instruments. These include determining origin and extent of hazes and dust clouds and, more importantly, locating vaporous clouds or frost patches which could indicate moisture-bearing soil. Such places are likely landing sites in 1973.

The presence of water now, or in the past, is a key factor in the search for Martian life, Horowitz says. Meanwhile, analysis of the Martian atmosphere may provide hints of life-related chemicals.

"If there is life on Mars, it will almost certainly be carbon-based, just as it is on Earth," Horowitz explains. "Carbon is the one element able to build the large, complex yet stable, molecules fundamental to organic life. If life is based on carbon and Mars' atmosphere is mostly carbon dioxide, it would be impossible for life not to interact with that atmosphere."

Until instruments and diggers land on the planet itself, Horowitz and his colleagues cling to that slight hope that life, however submicrobial, may exist on Mars. It could be no more than tiny algae, such as JPL scientists have found in Antarctica's permafrost. Some antarctic soil samples, on the other hand, appear to be completely sterile.

The Mariner '69 camera system is the most sophisticated yet devised for a planetary spacecraft. The two cameras, called A and B, will alternate to take pictures every 42½ seconds during the flyby at a range from 6,000 to 2,000 miles. They will be set so their fields will overlap. This will enable both panoramic shots and closeups of interesting details within panoramas.

Camera A is essentially the same as the Mariner IV camera, except a wide-angle lens has replaced a small telescope. Its resolution will still be about two miles (as in 1965), but, given an approach three times closer and the wider lens, each exposure frame will be about 15 times larger.

Camera B, using a Schmidt cassegrain telescope, is expected to produce pictures ten times sharper than Camera A, and at nearest approach, narrow down to areas comparable to a large city block. Camera A employs red, green and blue filters, Camera B yellow. All pictures transmitted will be black and white.

An improved vidicon tube will store and transmit images. Its photosensitive surface receives 704 lines, with 945 dots (called pixels) per line--665,280 dots for each exposure. An electronic beam scans these for a tape recording system that will relay them to Earth receiving stations in the NASA-JPL tracking network. The quality of the pictures should be upgraded by the 30-fold increase in pixel-pickup since 1965.

The cameras are mounted on a scan platform that can be moved by Earth command 215 degrees in clockwise rotation and 64 degrees in an up and down (conic) fashion. As each Mariner approaches Mars, several days before encounter, the spacecraft's planet sensor will track the center of brightness and aim Camera B for its series of full-disc pictures of the planet. About 14 hours out, Mars will fill the entire frame. Final far-encounter pictures will zoom in on selected portions of the planet.

The scan platform then willsle3 on both azes to ready the various instruments for closeup measurements. They can be set according to pre-launch pattern, or by an updated plan decided upon during the 4-month-plus flight. It is possible to change plans up to the last day before encounter. The near encounter picture taking sequences will last about 17 minutes, and the other instruments will continue to make measurements on the shadowed, night-time side of the planet.

An added fillip may be provided by closeups of one or both of Mars' tiny moons. It is possible that the inner moon, Phobos, 12 miles in diameter, could be picked up by the cameras as it swings close to a limb (outer edge) of Mars. Phobos' orbit is about 4,000 miles from the planet. The outer moon, Deimos, only six miles in diameter, presents a less favorable target, 12,000 miles out.

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FOR RELEASE: AM's OF TUESDAY, JULY 29, 1969

PASADENA, Calif.--The north equatorial zone of Mars varies 8.3 miles--roughly 44,000 feet--in altitude, radar astronomers of Caltech's Jet Propulsion Laboratory reported on the eve of the Mariner VI and VII fly-bys of the planet.

Their findings also included corrected figures for the ephemeris, or orbital path, of Mars.

The radar readings, obtained at JPL's Goldstone Tracking Station near Barstow, Calif., are expected to assure the accuracy of television cameras and other scientific experiments aboard the Mariners. Mariner VI is scheduled to fly by Mars about 10:18 p.m. (PDT), July 30; Mariner VII, about 10:00 p.m. (PDT), August 4.

The central portion of the Mars equatorial zone, to be photographed from 2,000 miles out by Mariner VI, is relatively flat, according to Dr. Richard Goldstein, who directed JPL radar measurements of the planet. However, the Martian highlands of Tharsis and the lowlands of Amazonis may appear in long-range, far-encounter pictures each Mariner will take for two days prior to the 17-minute closeup fly-bys.

Between Tharsis and Amazonis, the radar signals revealed the 8.3-mile difference in height. Both areas lie in the band from the Martian 10-degree north latitude circle to the equator. This was the principal area studied in 15 observations by the JPL group from May 7 through July 15. Goldstein said some 400 points on Mars were observed and re-observed.

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The altitude variation is similar to that found along Earth's equator--which has South American and African peaks 17,000 to 20,000 feet and and ocean floors even deeper. While there are no known seas on Mars, Amazonis could be cratered, but the studies of Goldstein's group cannot verify this yet.

Each radar beam in the JPL observation series probed a 37-by-100 mile spot on the surface of Mars during the planet's closest approach to Earth. (The closest distance was about 45 million miles on June 9.) The altitude readings represent an average for each 3,700-square mile patch. Because of this limited resolution, Goldstein adds, individual peaks or craters are not observable.

Among the interesting areas studied were the dark regions of Syrtis Major and Trivium Charontis, both well-known to astronomers. Syrtis Major was found to be a 500-mile-long slope, rising gently, one or two percent, to a higher plateau called Aeria. The high point of Syrtis Major was measured at about 20,000 feet. Trivium Charontis also appears to be a long slope.

The central region to be photographed closeup by Mariner VI--ranging from Xanthe through Meridiani Sinus--seems to slope gently downward toward the East, according to the new JPL radar work. The altitude change may be a mile or so.

The new findings will be of extreme interest to astronomers because they show that areas which appear light to telescopes may be either high or low in elevation, Goldstein says. Areas which are dark optically appear to be of medium elevation to radar-scanners.

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In the older speculation about Mars, astronomers thought dark areas on the planet were lowlands because dark areas on the Moon were low. After early radar measurements indicated this was not so, speculation swung to the view that dark areas were highlands. After this season's measurements, Goldstein concludes: "It is unlikely that all dark areas will be the same, and it is just as unlikely that bright areas will be the same."

The updated ephemeris calculations for Mars were made by Dr. William G. Melbourne, JPL Systems Analysis Research manager. With the aid of the radar pinpointing, believed accurate to within one-tenth of a mile, Melbourne shifted the position of Mars 250 miles relative to Earth by 150 miles relative to the Sun. These new figures have been taken into consideration by the JPL team guiding the Mariners in the National Aeronautics and Space Administration's planetary project.

Radar astronomy has steadily improved the ephemerides and topography of the planets during this decade. Goldstein, manager of JPL's Communications Systems Research Section, and his colleagues also have been active in radar-mapping Venus and monitoring pulsars, distant bodies (perhaps neutron stars) which emit radio pulsations.

During the Mars oppositions (closest approaches) of 1963 and 1965, Goldstein and his staff made similar studies using only 85-foot antennas at Goldstone. He believes the 1969 results to be far more accurate because of the 210-foot receiver and an increase in transmitting power, from 100 to 450 kilowatts.

It takes 10 minutes round trip for the 12½-centimeter wavelength signal to leave an 85-foot transmitter and bounce back from Mars to the 210-foot receiver. Beams which leave with a power of 450,000 watts return as barely audible echoes.

Yet the slightest variation in the elapsed time for each echo enables radio astronomers to compute the elevation of the reflecting surface points of the planet under observation. Time differences are measured in microseconds--millionths of a second. There was only 80 microseconds difference between the signal times that spelled 8.3 miles in a 90-million mile round trip.

The Martian altitude variation seems comparable to Earth's. Mars, with a diameter of 4,200 miles, has an apparent variation of 44,000 feet. Earth, 7,900 miles in diameter, varies more than 65,000 feet. (Mount Everest is 29,028 feet above sea level and the Mariana Trench in the Western Pacific Ocean extends to 36,198 feet below sea level.)

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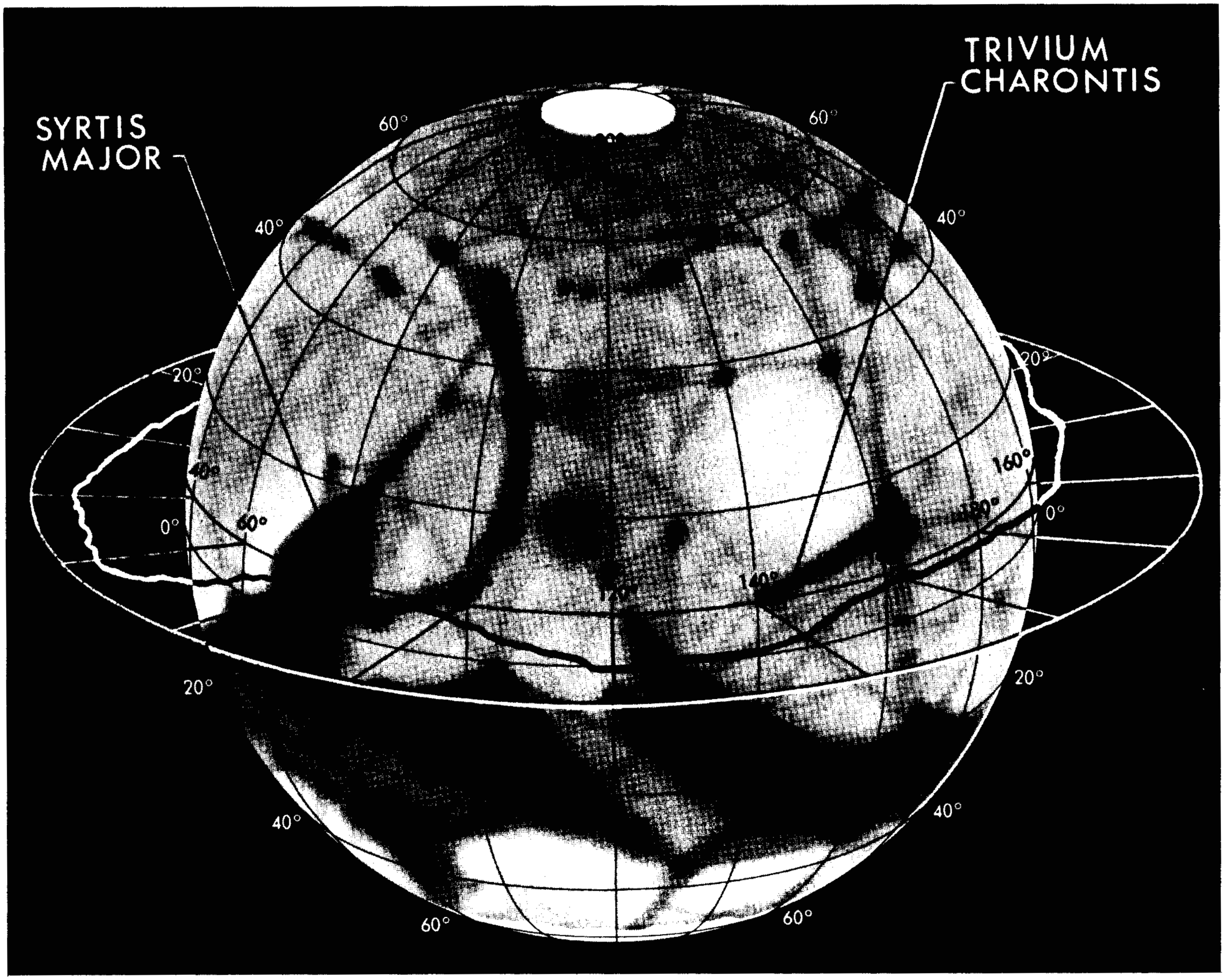

PHOTO CAPTION 331-4539

MARS'MIDDLE MAPPED: Radar astronomers of Caltech's Jet Propulsion Laboratory have come up with this 1969 topographical outline of Mars, 8 degrees north of the equator. In a series of 15 radar probes from JPL's Goldstone Tracking Station, the planetary surface was found to vary 8.3 miles, and to be quite irregular as shown by the inner black-and-white line. Syrtis Major and Trivium Charontis were found to be long slopes. The higher elevations--white line at left--toward Mars' western face are five miles or more. The outer white circle indicates a six-mile-high scale. This was topped at Tharsis on the other side of the planet. Mariner VI, the first of two Mars spacecraft, will fly by the equator July 30, probably on the other side of the planet. JPL conducted the radar research for the National Aeronautics and Space Administration.

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FOR RELEASE SUNDAY, SEPTEMBER 7, 1969

PASADENA, Calif.--A STAR computer for the outbound journey to the stars--believed to be the first able to detect its own failures and repair itself--begins full-scale ground operation this week at Caltech's Jet Propulsion Laboratory.

The STAR--for Self-Testing-and-Repairing--computer has passed preliminary tests, and JPL researchers have built the first breadboard model for the spacecraft guidance systems of the 1970s and '80s.

With the advanced computer, JPL space planners hope to perfect a fault-tolerant "brain" that will direct unmanned spacecraft on years-long missions to the outer planets--and beyond, into intergalactic space.

"We are aiming for 90 per cent probability of lasting 15 years," says Dr. Algirdas Avizienis (Ph.D.), JPL computer expert and father of the STAR project. That would be sufficient to control spacecraft operations to Neptune or Pluto, outermost targets in multi-planet Grand Tours of the solar system envisioned for the late 1970s by JPL for the National Aeronautics and Space Administration.

Dr. Avizienis will report on the STAR at an aerospace computer systems conference to be held September 8 through 10 in Los Angeles. The conference is sponsored by the American Institute of Aeronautics and Astronautics.

During its 9-to-11-year minimum lifetime, the STAR computer would automatically switch on identical backup units to replace parts that break down. Each part would have three or more standby replacements. A trip to Neptune, via Jupiter and Uranus, would take 7 to 9 years; the journey to Pluto, by Jupiter and Saturn, up to 11 years.

By 1974, a more modest STAR (with two backups for each part) may control a spacecraft on a flight to Jupiter alone--a 1½-year minimum undertaking.

In addition to its basic space application, STAR could aid in automating hospitals and controlling supersonic passenger aircraft of the future, Avizienis says.

Avizienis, Lithuanian-born computer scientist-engineer, conceived the star idea in 1961. Since 1965, he has guided a JPL group in its design, construction and development. He also teaches computer design as an associate professor at University of California at Los Angeles.

Assisted by a JPL team of a dozen engineers and technicians, he has built a 10-unit computer that uses a coding system to detect errors, and a monitor unit to diagnose the cause and cure in one one-hundredth of a second.

While the STAR test model fills three six-foot racks now, Avizienis says its parts can be miniaturized easily to fit spacecraft requirements. The flying STAR probably would not exceed two cubic feet, nor consume more than 50 watts of electrical power--less than an ordinary kitchen light bulb.

During flights, moreover, the self-healing computer will have the unique capability, Avizienis asserts, of detecting external interference, ascertaining the undesirable changes it causes in internal spacecraft functions, and then correcting errors before they become damaging to the spacecraft mission.

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"STAR can do everything but anticipate errors," he says, joking. "That will take a little more engineering."

How does the computer heal itself?

STAR belong to the digital family of computers. These operate with "words" of instructions and numeric quantities represented by strings of zeroes and ones (1010, 0011, etc.). All of STAR's instruction and number words are so chosen that a fault will change a good word to a meaningless or "illegal" one.

When a faulty unit sends a damaged word to another unit, the illegal word can be spotted by the monitor and its source identified. "A parallel exists in human affairs," Avizienis observes. "When a person starts mispronouncing or slurring words, illness or intoxication is suspected."

The monitor which "blows the whistle" on the faultmaker is called TARP--Test And Repair Processor. Literally the brain and conscience of the computer, TARP receives status reports from all working units and, in effect, decides whether all behavior is normal, that is, if each unit is following instructions and producing only good words.

Furthermore, like any good conscience, TARP also checks itself. For this TARP is built like a three-lobed brain. The computer actually has three active monitors, which operate by majority vote.

Whenever at least two monitors indicate an anomaly somewhere along the line, the decision is made to repair the malfunction. The suspected unit is tried once more, then replaced if it persists in its errors.

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If the "vote" has been two-to-one, the majority members of the TARP unit disconnect the power of the disagreeing monitor and replace it with a spare. Later, the rejected member may be tried again and re-used if the previous fault proves temporary.

Avizienis is convinced the theory of fault-tolerance and self-repair will apply to all facets of extended space flight. He visualizes the STAR computer as serving as the monitor and "automatic repairman" for in-flight testing and maintenance of the entire spacecraft, whether the mission be to Jupiter, Pluto, or the stars beyond.

Such self-control and self-repair will be imperative thousands of million miles out in space, where transmission times for radio commands from Earth to the spacecraft will be excessively long. A radio signal from Earth to the vicinity of Neptune or Pluto, for example, would take some four hours, and four more hours would pass until a reply arrived.

"The STAR computer team hopes not only to make a useful contribution to long space exploration voyages in the '70s," the JPL cyberneticist adds. "We hope also to raise the reliability of computers in other critical applications where human lives depend on fault-free performance."

On Earth, specifically, STAR could speed the development of the automated hospital. Avizienis says this computer could monitor 100 to 200 bed patients, cutting routine work to a minimum for physicians and nurses. STAR could take routine measurements every second, look for abnormalities, and ring an alarm when something goes wrong in any bed in the ward or hospital.

Moreover, failure of one of its own parts would not cause STAR to forsake its vigil. Within 1/100 of a heartbeat, the faulty unit would be replaced by a spare. Then the computer would request repair and return of the rejected unit to its spare part bank.

Such split-second action also may save anxious moments for pilots of future supersonic passenger planes, and for astronauts on extended manned spaceflights in the coming decades. Explains Avizienis:

The flight-control STAR would automatically handle most malfunctions, making spare-part substitutions as needed. Only in rare cases of overwhelming fault conditions would the computer request the pilot or co-pilot to take over. And that alarm would be registered within a tenth of a second.

STAR's success climaxes seven years of research and development in the JPL flight computer and sequencer section. Avizienis designed the first experimental model in 1965-66, with the aid of Allen Weeks and David A. Rennels, who now head the hardware design effort for STAR.

The STAR programming (software) team is led by John Rohr and Frank Mathur. John J. Wedel Jr. has been project administrator. William F. Scott is section manager. Other specialists are designing severe tests for the full-scale model and, looking ahead to the 1970s, developing applications for STAR in NASA space exploration programs.

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Two important outside contributions were noted by Avizienis. The Stanford Research Institute developed a magnetic power switch to disconnect faulty units, and the Massachusetts Institute of Technology Instrumentation Laboratory built the system's "read-only" storage unit for permanent programs.

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FOR RELEASE: TUESDAY A.M.'s, SEPTEMBER 23, 1969

PASADENA, Calif.--Has the moon always been as dead as it appears now?

The question could be answered, in part, at least, by three experiments to be conducted on Apollo 11 moon rock and soil samples by scientists of Caltech's Jet Propulsion Laboratory.

Three JPL scientists are among 142 researchers in this country and abroad who have been selected by the National Aeronautics and Space Administration to analyze the lunar material.

Whether any form of life might have existed on the moon will be the concern of Dr. Joon H. Rho, bioscientist. The effect of solar and cosmic radiation on lunar rocks will be studied by Douglas Nash, geologist. And Dr. Stanley L. Manatt, organic chemist, will head a probe into the outside chance that water molecules exist in the moon's soil.

The JPL lunar soil and rock studies will begin following the arrival of the precious samples from Houston.

Dr. Rho will attempt to find some trace of organic material in the 10 grams of rocks--mostly sub-surface--which he is receiving from core samples. These cores were drilled by the astronauts to a depth of 10 and 15 centimeters (about 3½ and 5½ inches) below the lunar surface. (Ten grams is about one-third of an ounce.)

The researcher will be looking for porphyrin, the basic ingredient of all life. Porphyrin is found in chlorophyll in plants and in blood hemoglobin in animal life. Traces of it can be found in fossils, or carbonaceous rock.

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The lunar soil will be washed in a series of chemical solvents in five and ten-gram batches. The extraction process, conducted over a two-month period, will break down the soil into its soluble organic compounds and mineral residues.

The solution will be subjected to ultraviolet fluorescent light beams in an instrument called a spectrophotofluorometer. If porphyrin compounds are present, the solution will give off a reddish glow at certain wavelengths of the light beams, Dr. Rho says. (These are in the 700-millimicron region.)

The instrument is so sensitive, Dr. Rho adds, that it will detect that presence of as little as one-trillionth of a gram of porphyrin.

"If we get a glow," Dr. Rho says, "it will be a good indication that past life may have existed on the moon. We don't think there is much chance of present life."

For comparative dating of the samples' ages, Dr. Rho and his team also will test two Earth rock samples. One is a fossilized rock 1.05 billion years old taken from the shore of Lake Superior in northern Michigan. The other is a 1.9 billion year-old rock with apparent traces of blue-green algae taken from Ontario, Canada. Rho's associates include Al Bauman, JPL; Prof. James Bonner, Caltech; and Dr. T. F. Yen, USC.

In the study by Nash's group, lunar rock chips and soil will be placed in vacuum chambers and bombarded with low-energy protons to simulate the solar wind, and with ultraviolet radiation to reproduce solar electromagnetic irradiation. Nash received 18 grams of moon soil (about 6/10 of one ounce).

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The rocks will be broken into chips no larger than 3/4-inch in diameter to fit into the scientific apparatus. Most bombardments will last only several hours, to correspond to normal lunar day.

However, Nash says some samples may be exposed to a continuous 10-day radiation equivalent to 50,000 years exposure on the moon.

During and after the radiation treatment, the moon rocks and soil will be studied with a spectrometer and other instruments to determine their luminescence and the chemical and mineralogical changes that may have occurred.

This spectrometer specifically measures the energies and color components of the stimulated light emitted by the samples. An infrared radiometer will measure the temperatures of the rocks.

Nash, who is group supervisor, will be joined in the proton irradiation laboratory study by Dr. James E. Conel and Dr. Raymond Greer.

The experiment to determine if water molecules or atoms of hydrogen are present in lunar soil will employ a technique called nuclear magnetic resonance. Dr. Manatt and his team will also seek to identify atoms of oxygen, aluminum, carbon, boron, nitrogen, fluorine, sodium, phosphorus, chlorine and bromine in 28 grams of moon material. That's equal to one ounce.

The atomic nuclei of these elements will be identifiable in the soil through their interactions with radio frequency energy (radio waves) when a sample is placed in a strong magnetic field. The excitation, or proton spinning, of these atomic nuclei should provide clues as to their chemical environment.

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The researchers also hope to establish whether deuterium, the heavy hydrogen isotope, may be present.

Dr. Manatt's research team includes Dr. Dan Elleman and Dr. Wes Huntress of JPL, Dr. Robert Vaughan, Caltech Assistant Professor of Chemical Engineering, Dr. Sunney I. Chan, Caltech Professor of Chemical Physics, and Dr. Fred Tsay, research associate in the Caltech Chemistry Department.

Drs. Chan, Tsay and Manatt will also perform electron spin resonance spectroscopy to ascertain the extent of radiation damage to lunar soil and identify other chemical elements. This technique involves the reactions of the so-called "unpaired" electrons, formed when high energy particles entér matter, with radio frequency energy in a strong magnetic field. These studies may permit detection of vanadium, iron, cobalt, carbon-hydrogen and carbon-nitrogen containing molecular fragments.

Neil L. Nickle of the JPL Lunar and Planetary Sciences Section served as acting assistant director for the NASA Lunar Sample Program in Washington, D. C.

(Note: all Drs. mentioned are Ph.Ds.)

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FOR IMMEDIATE RELEASE 10/29/69

PASADENA, Calif.--A microbiologist from Caltech's Jet Propulsion Laboratory may aid arid Morocco discover new land for increasing its agricultural potential.

Dr. Roy Cameron of JPL has just returned from the North African country where he and a New Mexico scientist conducted a 10-day field trip gathering samples of soil. Cameron brought back 58 pounds of soil from eight areas to undergo testing in his Soil Science Lab at JPL.

These will be cultured and tested for the presence of blue-green algae and other microorganisms which have potential for taking nitrogen from the air and increasing the fertility of the soil.

"The status of the soil and its possible use for farming are very important to the Moroccans," Cameron said. He and Prof. Eugene Staffeldt, mycologist (fungus expert) of the New Mexico State University, Las Cruces, N. M., performed the research mission under the auspices of the Smithsonian Institution.

The trip was arranged under the Smithsonian's foreign currency program which makes use of funds which United States agencies have received from the sale of surplus agricultural commodities. Prof. Albert Sasson, chief microbiologist of the Mohammed V University in Rabat, was Moroccan coordinator for the project, which is expected to continue two years longer.

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Most of the American scientists' field trip by jeep covered about 1,500 miles in the lightly populated area south of the Atlas Mountains at an elevation of 3,000 to 5,000 feet. The area, largely grazing land for sheep and goats, is similar to our southwestern desert, with average rainfall of less than five inches annually.

The undeveloped Moroccan area under study is on the western fringe of the Sahara Desert. Most of Morocco's 14 million people live in cities along the seacoast. The country's aridity and saline soil have hampered farming for centuries.

Dr. Cameron previously has made trips to Chile and Antarctica, collecting soil samples in connection with JPL's research into Earth regions believed similar to Mars and possibly other planets.

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